Japanese Technology Evaluation Center

JTEC

JTEC Panel Report on

Material Handling Technologies In Japan

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JAPANESE TECHNOLOGY EVALUATION CENTER

SPONSOR The Japanese Technology Evaluation Center (JTEC) is operated for the Federal Government to provide assessments of Japanese research and development (R&D) in selected technologies. The National Science Foundation (NSF) is the lead support agency. Paul Herer, Senior Advisor for Planning and Technology Evaluation, is NSF Program Director for the project. Other sponsors of JTEC include the National Aeronautics and Space Administration (NASA), the Department of Commerce (DOC), the Department of Energy (DOE), the Office of Naval Research (ONR), the Defense Advanced Research Projects Agency (DARPA), the U.S. Air Force, and the U.S. Army.

PURPOSE JTEC assessments contribute to more balanced technology transfer between Japan and the United States. The Japanese excel at acquisition and perfection of foreign technologies, whereas the U.S. has relatively little experience with this process. As the Japanese become leaders in research in targeted technologies, it is essential that the United States have access to the results. JTEC provides the important first step in this process by alerting U.S. researchers to Japanese accomplishments. JTEC findings can also be helpful in formulating governmental research and trade policies.

APPROACH The assessments are performed by panels of about six U.S. technical experts. Panel members are leading authorities in the field, technically active, and knowledgeable about both Japanese and U.S. research programs. Each panelist spends about one month of effort reviewing literature and writing his/her chapter of the report on a part-time basis over a twelve-month period. All recent panels have conducted extensive tours of Japanese laboratories. To provide a balanced perspective, panelists are selected from industry, academia, and government.

ASSESSMENTS The focus of the assessments is on the status and long-term direction of Japanese R&D efforts relative to those of the United States. Other important aspects include the evolution of the technology and the identification of key researchers, R&D organizations, and funding sources.

REPORTS The panel findings are presented to workshops where invited participants critique the preliminary results. Final reports are distributed by the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161 (703-487-4650). Panelists also present their findings in conference papers, journals, and books. All results are unclassified and public.

STAFF The Loyola College JTEC staff helps select topics to be assessed, recruits experts as panelists, organizes and coordinates panel activities, provides literature support, organizes tours of Japanese labs, assists in the preparation of workshop presentations and in the preparation of reports, and provides general administrative support. Mr. Cecil Uyehara of Uyehara International Associates provided literature support and advance work for this panel.

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FINAL REPORT

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ABSTRACT

This is the final report of the JTEC Panel on Material Handling Technologies in Japan. The study was sponsored by the National Science Foundation with additional support from Department of Defense and Department of Commerce. It examines the state of the art of advanced material handling research, development, and application in Japan in comparison to that in the United States. The focus is on automation inside warehouses and largely excludes automation in manufacturing and in transportation, except to the extent that involves storage and retrieval of material. Analysis is divided into five areas: trends in the material handling industry; the Japanese infrastructure; applications; equipment and systems development; and research. The report is based on a literature review and several trips to Japan, during which the panel members visited Japanese research and manufacturing facilities for material handling equipment as well as numerous sites where advanced material handling systems have been implemented.

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Foreword

This report is one in a series of reports prepared through the Japanese Technology Evaluation Center (JTEC), sponsored by the National Science Foundation (NSF) and administered by Loyola College in Maryland. The report describes research and development efforts in Japan in the area of material handling technologies.

Over the past decade, the United States' competitive position in world markets for high-technology products appears to have eroded substantially. As U.S. technological leadership is challenged, many government and private organizations seek to set policies that will help maintain U.S. competitive strengths. To do this effectively requires an understanding of the relative position of the United States and its competitors. Indeed, whether our goal is competition or cooperation, we must improve our access to the scientific and technical information in other countries.

Although many U.S. organizations support substantial data gathering and analysis directed at other nations, the government and privately sponsored studies that are in the public domain tend to be "input" studies. That is, they measure expenditures, personnel data, and facilities but do not assess the quality or quantity of the outputs obtained. Studies of the outputs of the research and development process are more difficult to perform since they require a subjective analysis by individuals who are experts in the relevant technical fields.

The National Science Foundation staff includes professionals with expertise in a wide range of technologies. These individuals have the technical expertise to assemble panels of experts who can perform competent, unbiased, scientific and technical reviews of research and development activities. Further, a principal activity of the Foundation is the review and selection for funding of research proposals. Thus the Foundation has both experience and credibility in this process. The JTEC activity builds on this capability.

Specific technologies, such as displays, telecommunications, or biotechnology, are selected for study by individuals in government agencies that are able to contribute to the funding of the study. A typical assessment is sponsored by two or more agencies. In cooperation with the sponsoring agencies, NSF selects a panel of experts who will conduct the study. Administrative oversight of the panel is provided by Loyola College in Maryland, which operates JTEC under an NSF grant.

Panelists are selected for their expertise in specific areas of technology and their broad knowledge of research and development in both the United States and in Japan. Of great importance is the panelists' ability to produce a comprehensive, informed and unbiased report. Most panelists have travelled previously to Japan or have professional associations with their expert counterparts in Japan. Nevertheless, as part of the assessment, the panel as a whole travels to Japan to spend at least one week visiting research and development sites and meeting with researchers. These trips have proven to be highly informative, and the panelists have been given broad access to both researchers and facilities. Upon completion of its trip, the panel conducts a one-day workshop to present its findings. Following the workshop, the panel completes its written report.

Study results are distributed widely. Representatives of Japan and members of the media are invited to attend the workshops. Final reports are made available through the National Technical Information Service (NTIS). Further publication of results is encouraged in professional society journals and magazines. Articles derived from earlier JTEC studies have appeared in *Science*, *IEEE Spectrum*, *Wall Street Journal*, *New York Times*, and others. Additional distribution media, including videotapes, are being tested.

Over the years, the assessment reports have provided input into the policy-making process of many agencies and organizations. Many of the reports are used by foreign governments and corporations. Indeed, the Japanese have used JTEC reports to their advantage, as the reports provide an independent assessment attesting to the quality of Japan's research.

The methodology developed and applied to the study of research and development in Japan has now been shown to be equally relevant to Europe and to other leading industrial nations. In general, the United States can benefit from a better understanding of cutting-edge research that is being conducted outside its borders. Improved awareness of international developments can significantly enhance the scope and effectiveness of international collaboration and thus benefit all of our international partners in joint research and development efforts.

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Executive Summary

Material handling plays a vital role in all sectors of business and commerce, but nowhere is it as important to an efficient operation as it is in manufacturing, warehousing and distribution. Those who study this field and understand how material handling methods, equipment and systems can be used to increase productivity look on the material handling process and the technologies available as strategic competitive factors. Cost reduction (capital and operating), increased throughput, improved response times, work place safety, and total quality are measures of performance that have strategic implications for a business. These factors are all directly affected by how well an organization performs its material handling functions.

These factors alone are enough to cause business leaders to want to study this field and to research best practices and available technology worldwide. The strategic advantages that many say Japan has in a wide variety of industries (e.g., automobiles and consumer electronics) present a particular impetus for studying developments in and applications of material handling in Japan. Japan's competitive position in high technology manufacturing helped motivate the National Science Foundation, the Department of Defense, and the Department of Commerce to commission an expert panel to conduct a study of material handling in Japan that would include visits to Japanese suppliers and users of material handling technologies.

This report synthesizes the findings from approximately sixty site visits, attendance at major Japanese trade exhibitions, a review of current literature, and discussions with numerous Japanese experts in the field. Although much of the research was conducted during the first five months of 1992, visits dating back to 1990 provided additional valuable information. A summary of the conclusions drawn from this study follows:

1. *Prior to 1960 Japan trailed the United States in industrial productivity and in the application of modern production methods, especially in the use of state-of-the-art material handling technology. All that has changed.*

In the late 1950s the Japanese Productivity Center sent a team to the U.S. to study what was being done in material handling and to recommend measures for implementation in Japan. The result was the licensing of U.S. material handling technology for production and use in Japan. Today, we see spin-offs and derivations of that early technology, which has improved vastly in several areas. Japan is not only using its own material handling technology and equipment domestically, but Japanese suppliers are selling them on a worldwide basis, including in the United States. Japan is now a leader in several equipment/technology categories.

2. *Productivity improvement--and the strategic advantages that accompany such improvement--have provided the rationale for Japan's quest for the best production methods and technologies over the last thirty years. However, that rationale today is being amplified manyfold by changing demographic, social, and business conditions in Japan. The result has been an acceleration in the application of automated material handling systems that dwarfs what we see occurring in the United States.*

The evidence is fairly clear that factors such as declining population, aging work force, changes in work preferences, and the ever-present congestion and lack of space are fueling the use of automation in Japan. The corollary in this case is that demand (application and use of automated material handling technologies) fuels supply, which translates into a rationale for ongoing research and product development. In many cases, economies of scale in the production of material handling equipment can also be associated with high demand levels.

3. *Automated material handling equipment and systems in Japan are not deployed exclusively in large, complex integrated systems. The result is many examples of simple, stand-alone installations.*

This factor partially explains the extremely high Japanese material handling equipment installation statistics in comparison to those in the United States. In the United States such installations are often called "islands of automation," and are generally viewed as less than desirable. In Japan, however, stand-alone installations mean greater control and cost savings. Two business factors have contributed to greater use of simple, stand-alone installations in Japan. One is the general Japanese attitude that simple is best. The other is the availability of Japanese users willing to make use of such systems without demanding often costly modifications and "bells and whistles." A benefit of this phenomenon is that it has allowed Japanese suppliers to concentrate on research and development that focuses more on issues such as product reliability and maintainability.

4. *The Japanese government has taken an active policy role in stimulating the application of automated material handling systems.*

The 1958 study team is perhaps the earliest, albeit an indirect, example of Japan's active government policy. A more direct example has been the Japanese government's policy of making funds available at attractive lending rates for capital projects that address demographic changes in the Japanese work force. The strategic significance of investments, coupled with a long-term view of their benefits (versus short-term payback), has long been recognized as something that differentiates Japanese attitudes about capital investments in business infrastructure from attitudes in the United States. The added motivation of having access to capital at attractive rates for the specific purposes stated above only compounds the advantages enjoyed by Japanese manufacturers.

5. *Research and development in the field of material handling, though very active, is apparently performed exclusively within the confines of private industry.*

This is no different from what takes place in the United States or elsewhere. In the United States, however, there is evidence of greater academic interest in the field of material handling. This has led to the direct incorporation of material handling into U.S. college curricula, and to more independent research associated with the operational design and control of material handling systems. This is not to be confused with electro-mechanical design or testing. There is little to no work of this type underway at U.S. or Japanese universities. Nevertheless, there is greater evidence of industry sponsorship of college and university material handling education and research in the U.S. than in Japan. There is somewhat of a dichotomy here because the rate of investment in material handling automation in Japan far exceeds that in the United States, regardless of what is done in or by universities.

6. *Industrial productivity in Japan still lags behind the productivity of U.S. industry, but the two have been converging rapidly.*

Japan's material handling practices have contributed significantly to its gains in productivity. The gains have been made possible by the enlightened attitude of Japanese business managers, the types of products and systems that Japan's material handling industry delivers to the market place, and the way that Japanese suppliers and users work together to accomplish an objective.

7. *An assessment of whether Japan is ahead or behind in its material handling technology depends on the technology being examined.*

A broad spectrum of equipment categories is analyzed in Figure Exec.1. The acronyms used in this figure are explained in the Glossary (Appendix F). In the status columns, "+" means Japan is ahead, "O" means that the U.S. and Japan are about even, and "-" indicates that the U.S. is ahead. In the trend columns, an upward pointing arrow indicates that Japan is gaining ground on the U.S., a horizontal arrow indicates that the current status is not changing, and a downward pointing arrow indicates that the U.S. is gaining ground on Japan. For example, Japan is clearly ahead and gaining over the U.S. in the application of automated storage and retrieval systems (AS/RS), automatic guided vehicles (AGVs), and automated electrified monorail (AEM) technologies. On the other hand, the U.S. is ahead of Japan and gaining in both development and application of advanced carousel material handling equipment.

CATEGORY	DEVELOPMENT status	DEVELOPMENT trend	APPLICATION status	APPLICATION trend
AS/RS				
unit load	o	↗	+	↗
mini load	+	↗	+	↗
AGV				
unit	o	→	+	↗
small	o	→	+	↗
AEM				
unit	o	↗	+	↗
small	+	↗	+	↗
CONVEYOR				
transport	o	↗	o	→
sortation	−	↘	−	→
SORTING TRANSFER VEHICLE	+	↗	+	↗
DEPALLETIZING (for case pick)			o	→

+ = Japan ahead ↗ = Japan gaining ground

Figure Exec.1. Qualitative Comparison of U.S. and Japan in Material Handling Technologies (part 1)

CATEGORY	DEVELOPMENT status	DEVELOPMENT trend	APPLICATION status	APPLICATION trend
Carousel	−	↘	−	↘
Rotary Rack	+	↗	O	→
Intel. Pick Cart	+	↗	+	↗
Lt. Aided Picking	+	↗	+	↗
Clean Rm. Syst's	+	↗	−	→
CONTROLS:				
Radio Freq. machine cntrl			−	→
operator cntrl			+	↗
Dock Mgt.	+	↗	+	↗
Warehouse Mgt. Sys.			−	→
Auto ID			−	↘
EDI			−	↘
Implement. Time & Smooth Startup	+	→	+	→

+ = Japan ahead   ↗ = Japan gaining ground

Figure Exec.1. Qualitative Comparison of U.S. and Japan in Material Handling Technologies (part 2)

CHAPTER 1

INTRODUCTION

Edward H. Frazelle

BACKGROUND

The Japanese first began assessing U.S. material handling capabilities in the late 1950s. These assessments led to a variety of Japanese licenses of U.S. material handling products. The Japanese applied these licensed technologies and, motivated by the necessity to automate, developed and applied material handling technologies that have reached and surpassed those found in many areas in the United States. An example is automated material handling systems for clean room manufacturing. A study of Japanese clean room manufacturing operations conducted by SEMATECH found that the Japanese were two to five years ahead of the U.S. in the application and development of automated material handling systems for clean rooms. Japanese prominence in this area means that U.S. semiconductor manufacturers and clean room operators could be forced to rely on Japanese suppliers for material handling systems for clean room facilities. Material handling systems are the means by which manufacturing and distribution strategies are executed. Hence, U.S. semiconductor manufacturers may find their manufacturing strategy decisions heavily influenced by foreign concerns.

The circumstances surrounding clean room manufacturing could conceivably be duplicated in other industries. For example, two of the largest U.S. apparel and food manufacturers want to automate their distribution centers. Because of limited domestic options, they are forced to turn to Japanese suppliers for automated case-picking technology. Other developments by Japanese material handling suppliers include short lead times, low-cost automated storage/retrieval system (AS/RS) technology, artificial intelligence systems for pallet loading, light-aided picking systems, portable carousels, and miniaturized automated guided vehicle systems. Development of many of these systems has been motivated by severe land and labor shortages, but may create demand for themselves. An example is the new Eskay Corporation, a supplier of modular, miniaturized AS/RS technology and a subsidiary of Daifuku.

Based on these and other developments, the National Science Foundation (NSF), funded a preliminary assessment of Japanese material handling technology in Fall 1990. The results were surprising. Based on a week-long tour of applications of automated material handling systems in Japan and a visit to Logis-Tech '90, a major trade exhibition of Japanese material handling systems, the Japanese appeared to be well beyond the United States in the development and application of advanced, automated material handling systems in many markets. This finding was consistent with the findings of the recently completed SEMATECH study that focused on material handling systems for clean room operations.

The NSF's preliminary assessment stimulated a more the intensive assessment of Japanese material handling technology, sponsored by NSF, the U.S. Department of Commerce, and the U.S. Department of Defense. The assessment was conducted by a panel of industry experts organized to represent each of the professional communities involved in material handling -- users from the manufacturing, distribution, and defense communities, as well as consultants, suppliers, and academics. The assessment included extensive literature reviews; interviews with key users, suppliers, consultants, and researchers in Japan; visits to Japanese material handling trade exhibitions; and over 50 site visits to Japanese factories and distribution centers employing advanced material handling capability. The findings have been shared at professional meetings with over 2,000 material handling professionals and via articles in trade journals with subscribers numbering over 100,000 material handling professionals.

This report synthesizes the panel's findings, observations, and presentations. Chapter 1 defines material handling and describes the critical role it plays in manufacturing and distribution performance. Chapter 2 provides a review of the material handling industry in Japan and describes alarming trends related to the application of advanced material handling technology. Chapter 3 describes the severe economic and social conditions motivating the intense application and development of automated material handling systems in Japan. A comparison of socioeconomic conditions in the United States with those in Japan lead to preliminary conclusions concerning the appropriate level of deployment of automated material handling technology. Chapters 4 and 5 describe the application and development of Japanese automated material handling technology. Chapter 6 defines the status of research in Japanese material handling systems.

The report concludes with perhaps its most valuable contribution -- detailed site reports from Logis-Tech '90, the Japanese physical distribution technology show; a variety of material handling supplier factories and development sites, including Daifuku, Okamura Corporation, Ishikawajima-Harima Heavy Industries Co. Ltd., and Murata Machinery, Ltd.; and applications of advanced material handling systems in pharmaceutical manufacturing, wholesale drug distribution, book and magazine distribution, toiletries and personal products, discount apparel distribution, cosmetics, frozen foods, postal service, and mail order apparel distribution.

THE ROLE OF MATERIAL HANDLING

Working from the Material Handling Industry of America's definition, material handling is the art and science of moving, storing, controlling, protecting, and containing material. The role of material handling in factories and warehouses is perhaps best described by examining this definition in detail.

Material

Material may refer to bulk or discrete material. Bulk, nonunitized material includes coal, sugar, grains, shavings, and so forth. Discrete or unit load material includes packaged, cased, and/or palletized products. The decomposition of a typical unit load is illustrated in Figure 1.1. The focus of this assessment is material handling systems designed for discrete or unit load material handling.

Moving

Moving material is necessary to create time and place utility -- the value of having material at the right time, at the right place, in the right quantity, and in the right condition. The equipment and systems used to move material include the conventional, universal icons for material handling -- fork trucks and conveyors -- as well as the more sophisticated automated material transport devices, including automated guided vehicles, automated storage/retrieval machines, automated electrified monorails, carousel storage and retrieval systems, and automated sorting systems.

Storing

Storing material is necessary to buffer the rate of production and consumption, to improve the utilization of manufacturing resources, and/or to consolidate material for complete order shipment. The equipment used to store material is primarily racks and shelving designed to utilize the full clear height of a factory or warehouse and/or to improve material access. Systems for storing pallet loads include single and double-deep rack, drive-in-and-through rack, stacking frames, and pallet flow rack. Systems for storing loose cases and loose items include shelving, drawers and/or flow rack.

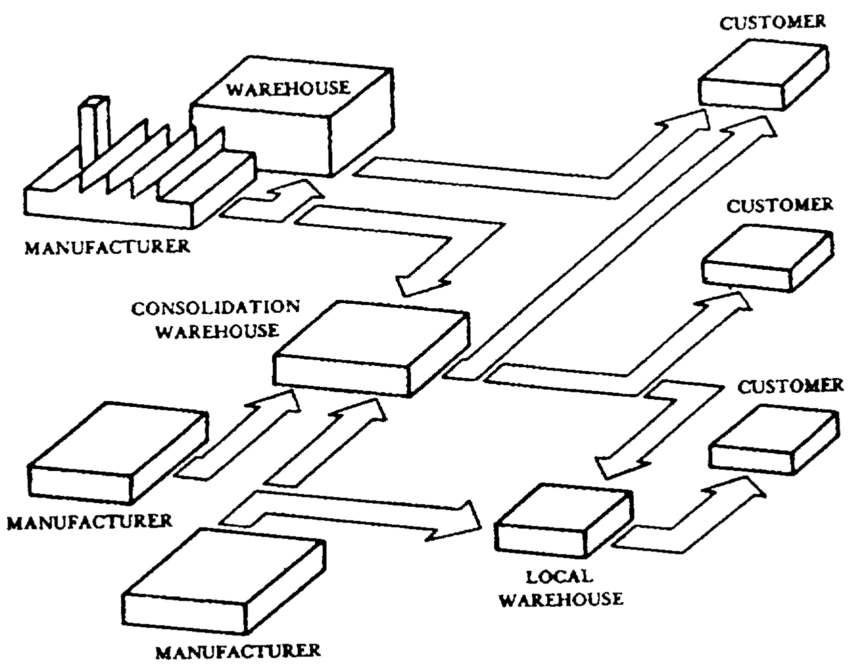


Figure 1.1. Decomposition of a Typical Unit Load

Controlling

Controlling material brings into play all those devices used to track, schedule, and prioritize material movement and storage. Typically included in this category are: Bar code printers, labels and symbologies; radio frequency terminals and communication and tags; light-aided picking devices; and all of the computer hardware and software used in synchronizing the flow of information and material. The Automatic Identification Manufacturers (AIM) Association and the Controls Product section of the Material Handling Institute represent suppliers of equipment and systems developed to control the flow of material and information.

Containing and Protecting

Containing and protecting material brings into play all those devices and systems used to contain material for ease of transport and/or storage, and to protect material from damage while in transit or storage. Devices and systems used to contain and/or protect material include packaging materials; cardboard cartons; plastic and metal tote pans; and wood, plastic, and metal pallets. The Society of Packaging and Handling Engineers represents the concerns of professionals working in the area of product protection and containment.

The Science of Material Handling

The science of material handling has emerged from years of research in the design, operation and integration of material handling systems. The resulting body of knowledge includes force and stress analysis in racking and lifting systems, queuing analysis of integrated material handling systems, economic modelling of investment decisions in material handling system justification, human factors analysis of manual material handling tasks, optimization characterization of alternative system design, simulation modelling of individual and integrated systems, and classical development work on the creation of new material handling devices and systems. Much of the research on the design, operation, and integration of material handling systems is conducted by academic professionals at U.S. universities. The Material Handling Industry of America's College Industry Council on Material Handling Education and Georgia Tech's Material Handling Research Center are representative of the academic professionals involved in material handling research and education.

The Art of Material Handling

The art of material handling has emerged from years of experience accrued by users, suppliers, and consultants. The Material Handling Management Society (MHMS, formerly the International Material Management Society), the Material Handling Institute, and the Association of Material Handling Consultants represent each of these communities, respectively.

With this characterization of material handling, it becomes easy to understand how material handling products and services account for annual sales in the U.S. in excess of $56 billion, and how in a typical factory material handling accounts for over 25 percent of all employees, 55 percent of all factory space, and 87 percent of all production time.

It is also not hard to understand how material handling plays such a vital role in the three major dimensions of competitiveness -- cost, quality, and timeliness.

Product cost is directly related to the operating productivity of a factory or warehouse, the ratio of the output of a factory or warehouse to the resources consumed in producing the output. Since such a large portion of the resources in a factory or warehouse are devoted to material handling activities, and since material handling is the means by which a manufacturing or distribution strategy is executed, perhaps no other activity plays as large a role in determining product cost as does material handling. A recent benchmarking survey of U.S. warehouses and distribution centers identified material handling techniques as the key determinant of warehouse operating efficiency.

Product quality is ultimately measured by the condition of the delivered product. Material handling plays a vital role in determining the ultimate condition of products since product protection is one of the missions of a material handling system and since the more frequently a product is handled, the more likely it is to become damaged. A recent survey found that between three percent and five percent of all material handling moves result in some form of product damage.

The timeliness of product delivery is increasingly becoming the means by which companies compete. Since most of a product's life in a factory or warehouse is spent in some material handling activity, material handling becomes the focal point in efforts to reduce total time to respond.

Material handling also plays a major role in work place safety. The majority of industrial accidents can be associated with material handling activities -- primarily manual lifting and industrial vehicle operation. Hence, improved design of material handling systems and increased application of automated manual handling should dramatically improve work place safety.

WAREHOUSING AND DISTRIBUTION

Material handling systems can be classified by the type of operation they are deployed in. The great majority of systems are deployed in factories serving a manufacturing mission or warehouses serving a distribution mission. The panel focused on the latter -- material handling systems in warehousing and distribution operations. The panel decided to select just one application because of the limited time available for conducting site visits in Japan. The panel felt its conclusions could be reported with a high degree of confidence with an increased sample size from a targeted application area. The decision to focus on warehousing and distribution applications resulted from several factors. First, although there is a wide range of material handling technology options in warehousing and distribution, it is narrower than that found in manufacturing. The difference stems primarily from the variety of product sizes and shapes found in manufacturing. Material handling systems in warehousing and distribution are generally designed around a narrow range of tote, carton, and/or pallet sizes. Second, through the numerous assessments of Japanese manufacturing techniques preceding this study and in the recently completed SEMATECH study, manufacturing applications had been directly and indirectly addressed. Finally, many of the factors currently affecting the design and operation of U.S. warehouses and distribution centers are similar to those affecting Japanese warehouses and distribution operations two to five years ago. The warehouses and distribution centers designed under those conditions are the focus of this study. Those conditions are reviewed below. In addition, for readers unfamiliar with warehousing and distribution operations, this study incorporates a review of the basic missions and functions of warehousing and distribution operations.

The recently completed 1992 Warehousing Education and Research Council's annual conference was titled "Meeting Increased Demands." It is no wonder.

The *just-in-time* operating philosophy has moved from manufacturing to distribution. Where it used to be sufficient to ship 100 units of a product on a Monday to complete a week's supply, today we must ship 20 units on each day of the week. The same amount of material is shipped, but there are five times as many transactions.

Quick response programs have reduced the amount of time allowed to respond to customer demands. Very quickly the standard for order cycle time is becoming same-day or overnight shipment. The compressed time schedules limit the available strategies for productivity improvement and place increased importance on the functionality and capacity of warehouse control and material handling systems.

The quest for quality has also moved from manufacturing into warehousing and distribution. As a result, the standards for accuracy performance have increased dramatically. Today, the average shipping accuracy in U.S. warehouses is about 99 percent. However, the Japanese standard of one error per 10,000 shipments is rapidly becoming the acceptable standard.

A renewed emphasis on customer service has increased the number and variety of value-added services in the warehouse. The extra services may include kitting, special packaging, label application, etc. For example, a large fine paper distributor counts and packages individual sheets of paper for overnight shipment. A large discount retailer requires vendors to provide slip sheets between each layer of cases on a pallet to facilitate internal distribution.

Increased emphasis on customer service and evolving consumer demand patterns in the U.S. have also increased the number of unique items in a typical warehouse or distribution center. The result, stock keeping unit (SKU) proliferation, is perhaps best illustrated in the beverage industry. Not many years ago the beverage aisle in a typical grocery store was populated with two or three flavors in 12-ounce bottles in six-packs. Today the typical beverage aisle is populated with colas (regular and diet, caffeine and non), clear drinks, and fruit-flavored drinks in 6-, 12-, and 24-pack glass and plastic bottles and cans and 1-, 2-, and 3-liter bottles.

Finally, an increased concern with the preservation of the environment, the conservation of natural resources, and human safety have brought more stringent government regulations into the design and management of warehousing operations.

The traditional response to increasing demands is to acquire additional resources. In the warehouse those resources include people, equipment, and space. Unfortunately, those resources may be difficult to obtain and maintain. Before the recent recession, economic forecasts identified a coming labor shortage. As the economy recovers we will again begin to experience the effects of the labor shortage. In addition, we will have to adjust to a work force characterized by advancing age, minority and non-English-speaking demographics, as well as by declining technical skills. New standards for work force safety and composition through OSHA's lifting standards and the Americans with Disabilities Act also make it difficult to rely on an increased work force as a way to address the increased demands on warehousing operations.

When labor is not the answer, we typically turn to mechanization and automation as a means of addressing increasing demands. Unfortunately, the United States' history of applying high technology in warehousing operations as a substitute for labor has not been distinguished. In many cases the U.S. has relied too heavily on high technology as a substitute for labor. In addition, high levels of technology are becoming more difficult to justify as capital becomes scarcer, as down-sizing becomes more prevalent, and as mergers, acquisitions, and the introduction of new competitors make it increasingly difficult to forecast the future.

Missions of a Warehouse

In a distribution network, a warehouse may serve any of the following requirements:

1. It may hold inventory that is used to balance and *buffer* the variation between production schedules and demand. For this purpose, the warehouse is usually located near the point of manufacture, and may be characterized by the flow of full pallets in and full pallets out, assuming that product size and volume warrant pallet-sized loads. A warehouse serving only this function may have demands ranging from monthly to quarterly replenishment of stock to the next level of distribution.

2. A warehouse may be used to accumulate and *consolidate* products from various points of manufacture within a single firm, or from several firms, for combined shipment to common customers. Such a warehouse may be

located central to either the production locations or the customer base. Product movement may be typified by full pallets in and full cases out. The facility is typically responding to regular weekly or monthly orders.

3. Warehouses may be distributed in the field in order to shorten transportation distances to permit *rapid response* to customer demand. Frequently, single items are picked, and the same item may be shipped to the customer every day.

Figure 1.2 illustrates warehouses performing these functions in a total distribution network. Unfortunately, in many of today's networks, a single item will pass in and out of a warehouse serving each of these functions between the point of manufacture and the customer. When feasible, two or more missions should be combined in the same warehousing operation. Current changes in the availability and cost of transportation options make the combination possible for many products. In particular, small high-value items with unpredictable demand are frequently shipped world-wide from a single source using overnight delivery services.

Functions within the Warehouse

Although it is easy to think of a warehouse as being dominated by product storage, there are many activities that occur as part of the process of getting material into and out of the warehouse. The following list includes the activities found in most warehouses. These tasks, or functions, are also indicated on a flow line in Figure 1.2 to make it easier to visualize them in actual operation.

1. Receiving
2. Prepackaging (optional)
3. Put-away
4. Storage
5. Order Picking
6. Packaging and/or Pricing (optional)
7. Sortation and/or Accumulation
8. Packing and Shipping

The functions may be defined briefly as follows:

1. *Receiving* is the collection of activities involved in: (a) the orderly receipt of all materials coming into the warehouse; (b) providing the assurance that the quantity and quality of such materials are as ordered; and (c) disbursing materials to storage or to other organizational functions requiring them.

2. *Prepackaging* is performed in a warehouse when products are received in bulk from a supplier and are subsequently packaged singly, in merchandisable quantities, or in combinations with other parts to form kits or assortments. An entire receipt of merchandise may be processed at once, or a portion may be held in bulk form to be processed later. This may be done

when packaging greatly increases the storage-cube requirements or when a part is common to several kits or assortments.

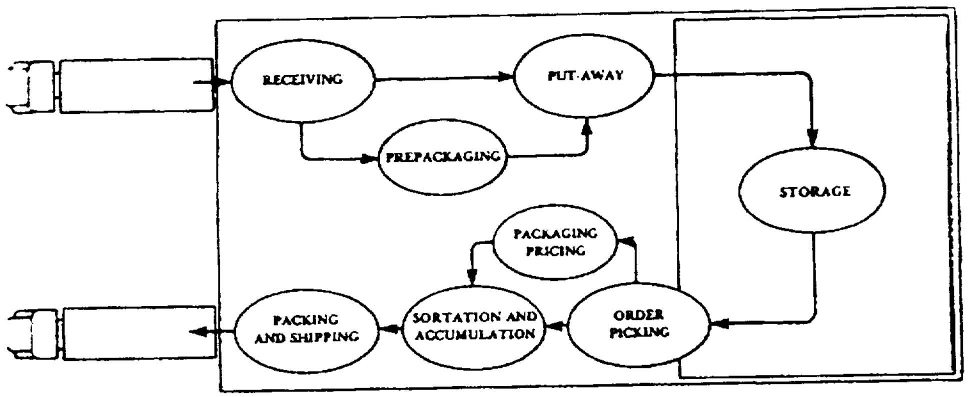


Figure 1.2. Warehousing Functions Found in a Total Distribution Network

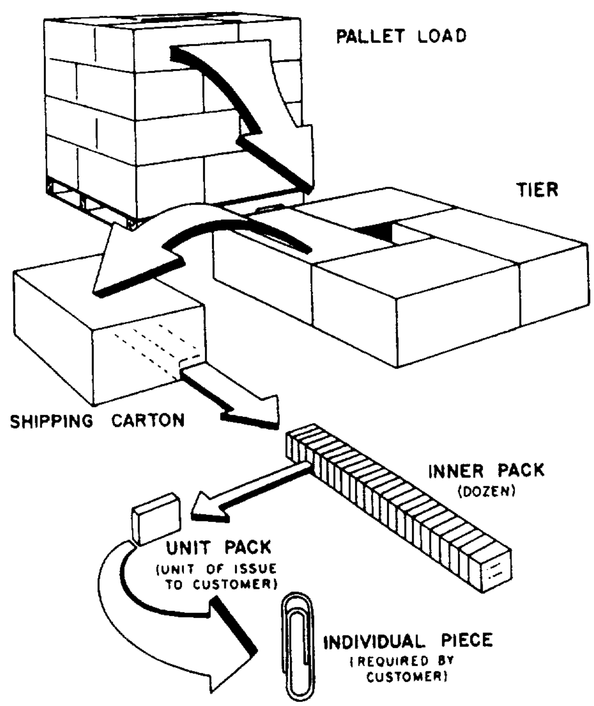


Figure 1.3. Flowline of Activities in Most Warehouses

3. *Put-away* is the act of placing merchandise in storage. It includes both a transportation and a placement component.

4. *Storage* is the physical containment of merchandise while it is awaiting a demand. The form of storage will depend on the size and quantity of the items in inventory and the handling characteristics of the product or its container.

5. *Order picking* is the process of removing items from storage to meet a specific demand. It represents the basic service that the warehouse provides for the customer and is the function around which most warehouse designs are based.

6. *Packaging and/or pricing* may be done as an optional step after the picking process. As in the prepackaging function, individual items or assortments are boxed for more convenient use. Waiting until after picking to perform these functions has the advantage of providing more flexibility in the use of on-hand inventory. Individual items are available for use in any of the packaging configurations right up to the time of need. Pricing is current at the time of sale. Prepricing at manufacture or receipt into the warehouse inevitably leads to some repricing activity, as price lists are changed while merchandise sits in inventory. Picking tickets and price stickers are sometimes combined into a single document.

7. *Sortation* of batch picks into individual orders and *accumulation* of distributed picks into orders must be done when an order has more than one item and the accumulation is not done as the picks are made.

8. *Packing and shipping* may include the following tasks:
   - checking orders for completeness
   - packaging of merchandise in an appropriate shipping container
   - preparation of shipping documents, including packing list, address label and bill of lading
   - weighing of order to determine shipping charges
   - accumulation of orders by outbound carrier
   - loading trucks (in many instances, this is a carrier's responsibility)

For the purposes of this report, *receiving* includes the activities described above as receiving, prepackaging, and put-away; in *order picking* the activities described as order picking, packaging, and sortation/accumulation; and in *shipping* the activities described as packing and shipping.

CHAPTER 2

TRENDS IN MATERIAL HANDLING

Richard E. Ward

INTRODUCTION

Japan's material handling trends can be viewed from several perspectives. One obvious trend is the growth of the industry in general and of certain equipment/systems categories in particular. Many readers will probably not be surprised to learn that material handling is a large and rapidly growing industry. However, there might be some element of surprise on learning of the sheer magnitude of end-user investments in material handling in the high-end, automated systems categories. Industry statistics (presented later in this chapter) indicate that when it comes to the implementation of automated material handling systems technologies, Japan is substantially ahead of the United States. First, however, a brief look at the industry's organization and its direction, both as an industry and as a professional field of endeavor, provide a useful backdrop for the statistics.

Organization of The Material Handling Industry in Japan

The industry analysis begins with a look at the suppliers. Most of the mechanical equipment producers and suppliers, certainly all of the larger ones, belong to at least one of two major organizations that come close to what are called trade associations in the U.S. The two are the Japan Industrial Vehicles Association (IVA), and the Japan Society of Industrial Machinery Manufacturers (JSIM). The Japan

Material Handling Society is a third, probably less significant organization, about which little information was available.

The Industrial Vehicles Association is probably very similar to the United States' Industrial Truck Association (ITA). In fact, because Japanese fork truck manufacturers are so heavily involved in the U.S. market, many Japanese companies are members of both organizations. However, unlike its American counterpart, IVA (although an independent organization) has a very close affiliation with the Japan Management Association (JMA).

The JSIM, on the other hand, is a very large organization whose members cut across many industries. It is not certain that an organization quite like it exists in the U.S. Perhaps one that comes closest is the Manufacturers Alliance for Productivity and Innovation (MAPI, formerly known as the Manufacturers and Allied Products Institute). The JSIM organization in Japan has some twelve department committees or sections, including Mining Machinery, Chemical Machinery, and Material Handling Machinery, for example. The material handling department consists of several subcommittees, including suppliers of automatic storage/retrieval systems (AS/RS), conveyors, cranes, hoisting machinery, elevators, and other automated warehouse systems. Automatic guided vehicle systems (AGVS) are represented in the IVA.

A striking difference between material handling trade associations in the U.S. and Japan is that the industry in the U.S. is represented by associations that are not part of a larger, multi-industry association. The ITA in the U.S. was already mentioned as an example. Another is the Conveyor Equipment Manufacturers Association (CEMA), which, in addition to representation from the package conveyors industry, also has heavy representation from the bulk/process conveying industry. The largest association in the U.S., which combines the Material Handling Institute (MHI) and the Material Handling Industry of America (MHIA), is independent and focuses only on material handling. These two entities are actually divisions of a parent holding association known as the *Material Handling Industry*. Although a detailed description of these organizations is not called for in this report, several factors differentiate MHI and MHIA from the Material Handling Section of JSIM, for example:

1. MHI and MHIA represent a broader cross section of the material handling industry in the U.S. Automated systems manufacturers, rack manufacturers, shelving manufacturers, metal and plastic container manufacturers, crane manufacturers, hoist manufacturers, controls and automatic identification manufacturers, and lift products manufacturers, are a few of those represented.

2. Both associations reflect the members' desire to influence public and business policies that can affect the successful operation and management of a material handling company.

3. MHI and MHIA have a focus on consumer education that facilitate business between suppliers and end users. This includes not only technical education, but also promotion of the concepts and principles that are the foundation of properly planned and engineered material handling installations.

4. The two organizations foster the growth and improvement of the industry through internal education, special programs such as industry-specific captive insurance programs, and business-to-business networking at regular, industry-wide business meetings.

5. Both associations are committed to fostering education about material handling at the collegiate level through very specific programs, such as scholarships and the sponsorship of teacher and research programs.

By comparison, there are few visible trends at the industry level in Japan that are comparable to the above. One similarity between the Japanese and U.S. associations is that both focus on promulgating industry standards and good application practices, especially in the area of safety. Another similarity is that market statistics are generated by both the Japanese and U.S. associations annually, and in some instances more frequently. One difference is that the Japanese associations show a greater willingness to share industry statistics with the public. This is far less true in the U.S., making it more difficult to research the U.S. material handling industry at almost any level. Some would argue that because the U.S. marketplace is in general far more open, not openly exposing industry statistics is the only defense a U.S.-based industry has against external competition.

Professional Associations

Japan is not unlike the U.S. in that there are a number of professional practice groups that represent the interests of the industry and persons whose livelihood is based on planning and designing material handling systems. The two major groups are the Japan Council of Logistics Management (JCLM) and the Japan Logistics Association (JLA). A third, whose name could not be confirmed, serves primarily the interests of academicians. There is also a production engineering association (similar to industrial engineering). But there was no evidence that there is much if any focus there on material handling. This is not true, for example, in the U.S. Institute of Industrial Engineers, whose material handling programs have traditionally been very visible.

What is so different about the JCLM and JLA is their very small membership levels when compared to their U.S. counterparts, such as the Materials Handling and Management Society (MHMS, formerly known as the International Materials Management Society), the Warehousing Education and Research Council (WERC) and the Council of Logistics Management (COLM). On the low end there is a minimum membership ratio of three to one (U.S. to Japan), and on the high end it is as much as fifteen to one. This almost appears to be inconsistent with the tremendously high levels of sophisticated material handling system installations observed in Japan.

One explanation for this is the very high proportion of Japan's association memberships that are made up of company memberships versus individual or professional memberships. This includes most of the major Japanese material handling equipment suppliers. Moreover, the memberships and activities of JCLM and JLA are very similar. A possible exception is JCLM's organization and sponsorship of one of the two major material handling trade shows in Japan (albeit the newer of the two). While the JLA does not directly organize any trade shows, it is nevertheless involved as a major cosponsor of the other major (and older) trade show that is organized by the Japan Management Association, which, as was explained earlier, has a close tie to the JLA.

If this appears a bit confusing to the reader, it also does to at least some in Japan -- so much so that great pressure has been placed on JCLM and JLA to merge. Most of the pressure is said to come from the Ministry of Transport (MOT) and the Ministry of International Trade and Industry (MITI). However, one would think that some of the pressure would also come from the industry (company) members themselves. Although there are not too many scenarios concerning the possible outcome, and even though an outcome is expected as early as the summer of 1992, no hard facts were available at the time of the JTEC panel's visit. If a merger occurred, a strong industry association like the U.S. MHI and MHIA could result, as could unified industry trade fairs, not unlike the annual fairs in the U.S. that are sponsored by the MHIA.

TRENDS

Application Trends

As indicated earlier, the level of Japanese investment in material handling systems, specifically automated technologies, was staggering in comparison to the U.S. To some extent, these investment data reflect the peculiarities of business conditions in Japan, which differ greatly from conditions in the U.S.

Let us first look at the trend in total sales of physical distribution systems inside Japan. This includes AS/RS (the largest single segment), conveyors, AGVS, carousels, palletizers, vertical conveyors, racks and shelving, computer hardware and software, and a category called "other". Figure 2.1 was extracted from a report given to the visiting JTEC panel by one of the largest material handling suppliers in Japan. These figures ($2.53 billion in 1990) do not include fork trucks and other manually operated, wheeled plant equipment. Nor do they include cranes, hoists,

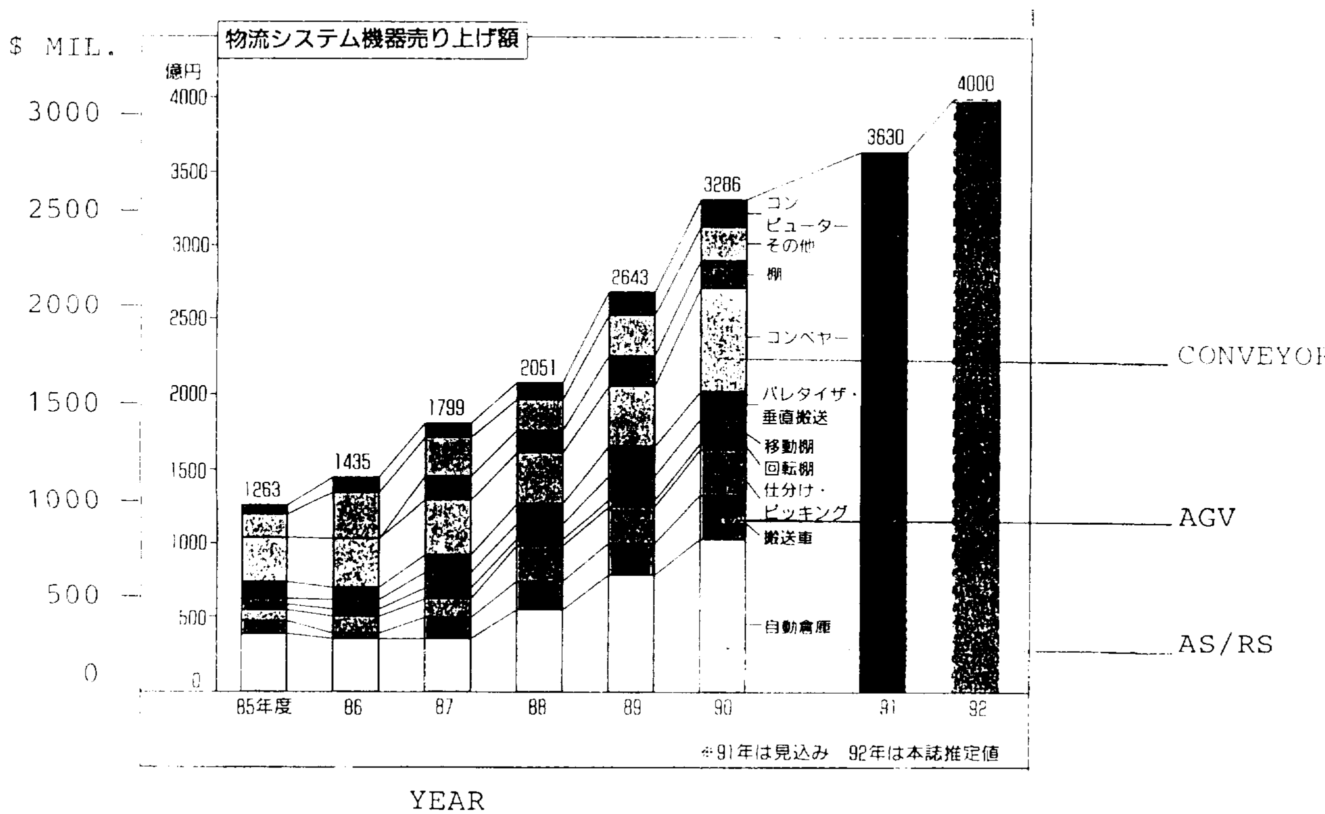


Figure 2.1. Total Sales of Physical Distribution Systems in Japan

monorails, pallets, or unit load containers, all of which are considered part of the total market in the U.S. Because of the difference in the way public domain statistics are collected in Japan and in the U.S., it is difficult to obtain an exact comparison. A very approximate comparable figure for the U.S. in 1990 would be $5.15 billion. Table 2.1 shows (approximately) comparable growth statistics for 1986 to 1992.

Several inferences can be drawn from these statistics. The first stems from an analysis of the level of investment in material handling equipment and systems as a percentage of each country's either Gross or Domestic National Product. Since both Japan's GNP and GDP are little more than half of comparable figures for the United States, and since Japan's investment statistics for 1990 are approximately half of comparable statistics for the U.S., 1990 was a threshold year for Japan: it was investing in material handling at proportionately the same level as the U.S. for the very first time.

Table 2.1
Growth in Sales of Material Handling Equipment in Japan and the U.S.
(percent)

	Japan	U.S.
1986	13.6	12.6
1987	25.4	- 3.5
1988	14.0	2.0
1989	28.9	7.2
1990	24.3	0
1991 (est)	10.5	- 2.0
1992 (est)	10.2	6.0

Source: Material Handling Industry Data Acquisition Service (MHIDAS) Database

Secondly, it is no coincidence that there is a strong correlation between the rate of change in Japan's investment in material handling infrastructure and the rate of change in the country's productivity levels. Although Japan still trails the U.S. in productivity, it has been gaining ground rapidly. If 1990 was a threshold year for Japan in terms of investment in material handling, and if the projections for continued strong growth in that investment are sustained, then there is reason to believe that Japan's productivity growth will accelerate into the 1990s. There is a very positive cause and effect relationship at work in Japan; and while material handling certainly is not the only causal factor, it most certainly must be viewed as a strong contributing factor to Japan's ability to compete in a world economy.

There is yet a third inference to draw concerning Japan's level of investment in material handling that is less flattering than the aforementioned. Given that the total level of investment in Japan and in the U.S. is proportionately equivalent; and given (as will be seen in the next section) that Japan invests far more heavily in automated systems (e.g., AGVS and AS/RS), it leads one to wonder (based on what is left over for investment in traditional, nonautomated equipment and systems) whether in fact there is a segment of Japanese industry that is either being neglected or that is at best receiving far less investment in its material handling infrastructure. Examples could be many small- to mid-size companies that operate much as they have for decades. In other words, the very large, high visibility Japanese companies may receive a disproportionate share of the total funds dedicated for plant and warehouse modernization. In fact there was evidence of this during the JTEC panel's visit to Banyu Pharmaceutical, when it was explained that the pharmaceutical wholesalers do not compare with primary (manufacturing) distribution centers when it comes to the installation and use of advanced, integrated material handling systems.

AS/RS Trends

Since two technologies that attract a lot of attention in the U.S. are AS/RS and AGVS, a more in-depth examination of trends in these two categories follows. However, first there will be a very brief examination of a third (fourth, if conveyors are included) significant growth category. This category, loosely translated as "picking/sorting systems", is shown as the block in the bar directly above AGV in Figure 2.1. This category, at least in this chart, includes fully automated case picking systems.

A total of 3,039 AS/RS machines (stacker cranes) were produced for installation in Japan in 1990. This number is many times greater than the number available in the U.S. market. Various reports place the number of machines sold in the U.S. in 1991 at about 300. Japanese AS/RS trend data, by type of system, are compiled in Table 2.2.

One significant fact is that the average number of machines per system is less than two. This number undoubtedly includes many small (single aisle) installations, which accounts for both the large growth and the much larger number of total installations. The Japanese user industry appears to seek out nontraditional applications that can benefit from AS/RS. Another trend that tends to support the growing number of nontraditional applications is the height of the system. The visiting team observed several examples of machines that were not much taller than two meters. Approximately 20 percent of the machines produced in 1990 were under five meters in height. A breakdown of systems in categories less than five meters was not available. For example, machines were seen in an office automation environment and as a means of staging and consolidating orders for shipping in a distribution center. Many of the recent installations have been pre-engineered systems, which help to reduce system cost and makes them more affordable. The largest single Japanese supplier of AS/RS claims that as many as 80 percent of its total AS/RS sales are pre-engineered systems.

There is also a growing trend towards using AS/RS technology for automobile parking in urban areas. However, this trend is not manifested in the statistics included in Table 2.2, and will certainly show up in the future as machines much larger than five meters.

AGVS Trends

Automatic guided vehicle systems installations in Japan totaled 580 in 1990. A comparable figure in the U.S. would be slightly in excess of 96, or a 6 to 1 (Japan to U.S.) ratio. Of equal interest, if not greater significance, is the difference in the average number of vehicles per installation. In Japan, in 1990, this average was a little more than 2¼ vehicles per system. In the U.S., the average exceeded five vehicles per system. There are several possible explanations of this trend and difference (although the U.S. average is dropping, especially following recent reductions in the use of AGVs in the automobile industry as an assembly deck):

1) Smaller end-user companies in Japan (compared to the U.S.) are finding value in the application of AGVs.

2) AGVs are more readily applied in Japan, since many of these are simple pick-up and delivery applications. However, the JTEC panel also saw installations with only one or two vehicles, where the daily routine was block stacking and staging unitized loads for shipment. Table 2.3 provides trend statistics for the Japanese AGV market.

Table 2.2
Trends in Japanese AS/RS Installations

Type of Installation	1985	1986	1987	1988	1989	1990
			Number of Installations			
Unit Load/Rack Supported Bldg.	92	95	92	115	115	87
Unit Load/Free Standing	570	562	575	782	1079	1164
Mini-Load/Rack Supported Bldg.	2	---	---	1	6	---
Mini-Load/Free Standing	77	82	95	146	253	383
			Number of Machines			
Unit Load/Rack Supported Bldg.	250	310	179	245	299	299
Unit Load/Free Standing	824	455	861	1108	1671	2040
Mini-Load/Rack Supported Bldg.	14	---	---	3	32	16
Mini Load/Free Standing	90	152	132	282	408	684
			Number of Face Openings			
Unit Load/Rack Supported Bldg.	189,267	134,665	122,025	209,643	311,290	303,411
Unit Load/Free Standing	198,695	141,811	255,286	263,611	421,901	520,941
Mini-Load/Rack Supported Bldg.	32,208	---	---	20,160	52,296	10,440
Mini Load/Free Standing	73,403	167,070	164,609	260,430	373,987	784,243

Table 2.3
Japan's AGVS Market

	1985	1986	1987	1988	1989	1990
Number of Installations	317	177	435	486	445	580
Number of Vehicles	934	645	946	1209	945	1326

Other Trends

The only other trend issues concern the application of automated electrified monorails (AEMs), or "smart monorails"; picking/sorting systems; and sorting transfer vehicles. Statistics for these equipment categories are not as good as the statistics for AGVs or AS/RS. Therefore, conclusions drawn risk being less accurate. Nevertheless, the following observations are made based on what was seen by the visiting team, what was being shown by suppliers, and the limited statistics available:

1. There is growing use of AEM in Japan as an alternative for the horizontal movement of unit loads, especially light loads (e.g., 30 kgs and less). What statistics were available indicate that there probably were no AEMs in use prior to 1987. By contrast, AEMs were in wide use in the U.S. prior to 1987 (albeit in the heavier load categories). AEMs have been used for some time in Europe.

2. Rapid, sorting transfer vehicles or car-in-track systems have become popular alternatives to handling the input and output of an AS/RS (versus conveyors or AGVs).

3. It is possible that automated case picking is more widely used in Japan. The panel saw excellent examples of this during the site visits. Moreover, supplier equipment catalogs promote this approach to case picking.

4. There is some evidence to suggest that "pick-to-light" or "pick director" order picking systems are becoming widely used, and not just in connection with loose case picking from carton flow delivery racks.

TECHNOLOGY EVOLUTION

Japan has produced material handling equipment for many years. However, a wave of technology transfer took place beginning in the late 1960s and early 1970s, where U.S. material handling (mechanical automation) technology was licensed for manufacture in Japan by Japanese companies. The same was true of European technology. Currently, there are at least seventy such technology licenses covering everything from wire containers, palletizers, conveyors, and cranes, to AGVS, AS/RS and other forms of material handling automation, including automatic identification and control devices.

There is little question that these original licenses and the corresponding patents are being improved upon by the Japanese license holders, and in some cases non-license holders. Opinions vary however, as to the probable outcome. One school of thought suggests that the improvements will remain in Japan, because of the difficulty of marketing and servicing automation business in the U.S. Another school of thought believes that these improvements will find their way back to the U.S. through return licensing agreements or through Japanese companies doing business in the U.S. Only time will tell which of these scenarios will prove most true.

SUMMARY

The above discussion outlines current trends in Japan's material handling industry. This industry is part of a dynamic environment and bears watching. In today's global market, U.S. companies compete directly with Japanese manufacturers, who are making heavy use of automated (material handling) technologies as a means of reducing costs, improving productivity, and improving service performance, both in production and distribution. Moreover, Japanese material handling equipment suppliers are becoming noticed in the U.S. marketplace, and they are bringing good products with them.

CHAPTER 3

THE JAPANESE INFRASTRUCTURE

James M. Apple, Jr.
Edward H. Frazelle

INTRODUCTION

The mission of this JTEC panel on material handling technology was not to study the general social and business conditions in Japan. However, to properly interpret our findings, it is important to understand the impact these business and social conditions have on the development and application of material handling technology. To the extent that similar business and social conditions exist in the United States, we might expect to see similar development and application of technology. If indeed the business and social conditions are similar, a Japanese advantage in the application and development of material handling technology would be significant. If the business and social conditions are drastically different, the differences may provide a rationale for differences in the application and development of technology.

The general consensus of the JTEC panel is that the Japanese have surpassed the U.S. in the development and application of material handling technology in many key areas. However, in instances where the Japanese are ahead, the U.S. should not necessarily conclude that it needs to move rapidly to catch up. The U.S. does need to be aware of how the meeting of a unique requirement in Japan may provide competitive advantage in another area, or at a later time when similar conditions may exist in the U.S. Also, to the extent that the U.S. focuses its development efforts on only those products that are right for the domestic market, the U.S. eliminates itself from an expanding worldwide market for material handling systems.

It is very difficult to isolate system design and justification factors and to attribute a specific product development to an individual factor. Many factors are interdependent, combining to provide a motivation for a particular level of modernization or a particular approach to system design. This discussion addresses design and justification factors individually and in combination to assess the impact on material handling technology and system design.

In general, the panel found a group of social and demographic factors that create a set of design requirements that is quite different from those that would typically develop in the U.S. Additionally, in Japan there are business factors at hand that enable a capital system that supports more expensive design requirements. The result is a level of mechanization significantly higher than would be considered appropriate in the U.S.

DEMOGRAPHIC AND SOCIAL FACTORS

The major demographic and social conditions affecting the design and justification of material handling systems in Japan can be classified under the general headings of commercial density, labor availability, and work force attitudes.

Commercial Density

Population density in Japan is nearly 12 times that of the U.S. Like the U.S., the population is clustered in and around metropolitan areas. The commercial density, measured in GNP/km^2, is almost 15 times that of the U.S. (see Table 3.1). As a result, land is scarce and expensive, particularly in heavily populated areas where distribution centers are needed.

With expensive land comes expensive parking and an overall high price of automobile ownership. Hence, a much higher percentage of the population depends on public transportation and on retail outlets located close to home. Interestingly, there are almost twice as many retail outlets per person in Japan (Table 3.2). These retail outlets are much smaller than those found in the U.S. In fact, a significant volume of merchandise in Japan is sold through vending machines. Space constraints within the stores severely limit shelf space so that products must be delivered more frequently in smaller quantities. Delivery cycles are more likely to be daily than weekly (Fig. 3.1).

Warehouse Activity Levels and Delivery. In translating these demographic and social factors into distribution requirements, products that would typically flow in full pallet quantities in the U.S. are moved in case quantities in Japan, and those that would typically flow in case quantities in the U.S. are moved as individual items in Japan. Hence, there is a much greater emphasis on equipment and control systems that increase loose-case and item-picking productivity, and on automation that eliminates manual case and item-picking altogether.

Table 3.1
Japan's Space Shortage
(1990)

	Population (millions)	GNP ($trillions)	Land Area (1000 km^2)	GNP per km^2	Home Size (sq. ft.)
E.C.	328	6.01			1,100
Japan	124	2.94	0.37	7.96	800
U.S.	251	5.13	9.37	0.55	1,773
U.S. vs Japan	2.02	1.74	25.32	0.07	2.22

Table 3.2
Retail/Wholesale Comparison

	Retail Stores (1000s)	Stores Per 10,000 People	Wholesale Outlets (1000s)	Outlets Per 10,000 People
Germany	410	67	119	19
Japan	1,620	132	437	36
U.S.	1,600	65	376	16

Another consequence of smaller, more frequent orders is the traffic congestion created by delivery vehicles. Delivery time, cost, and commuting time have increased to unacceptable levels. In fact, a high-ranking Japanese businessman was recently quoted as saying that "Just-in-time is the reason everyone is late." The need for change is well recognized and a committee sponsored by the Ministry of Transportation has been formed to identify alternative courses of action. Some remarkably creative and ambitious underground systems for product distribution have been proposed.

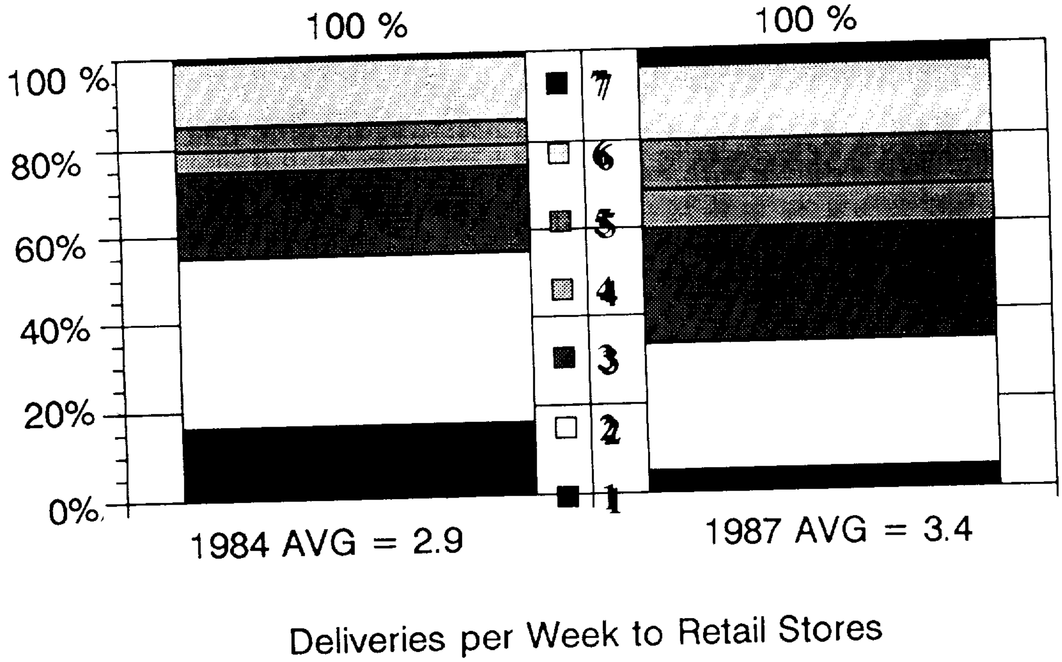


Figure 3.1. More Frequent Deliveries

Facilities Configuration. Scarce, expensive land makes multi-story manufacturing and distribution operations the norm. In fact, nearly all of the distribution facilities the panel visited were multi-story, usually three to six floors. As an example, the Shin Tokyo Post Office is three stories tall with almost 1,000,000 square feet on each floor. The third level includes 96 truck docks which are accessed by ramps at the rear of the site.

Necessity has forced the Japanese to develop excellent vertical material handling systems. Examples of between-floor handling devices included both reciprocating and continuous lifts and elevators, some of which are loaded and unloaded automatically, as well as high-rise automated storage/retrieval systems. Input and output stations are provided at multiple levels so that the storage system also performs as an elevator. This application of AS/RS technology is also found in the U.S., but not as frequently.

The Japanese have installed several times the number of automated storage systems as the U.S. The comfort level achieved with the technology and the economies of higher volume has permitted them to realize the benefits of high-rise AS/RS technology, even in small, single-aisle applications. In addition, to overcome the limitations of automated storage as we know it, the Japanese have concentrated on ways to increase throughput, including faster crane acceleration and travel, faster shuttle speeds, minimizing control system delays, and placing multiple cranes in a single aisle. For small load applications, we encountered systems with as many as five storage/retrieval machines in a single aisle. Each machine was only three to four feet high, and operated one above the other on formed steel channels attached to the rack, interfacing with fast lifts at the end of the aisle.

The U.S. material handling industry has long recognized the benefits associated with the controlled discipline of automated storage, but has struggled to justify the cost required to achieve adequate throughput. The Japanese have been persistent and creative in addressing the issue because they had to, and now enjoy a substantial advantage in the widespread application of automated storage technology, as well as in the economies of scale associated with the higher production volumes.

Labor Availability

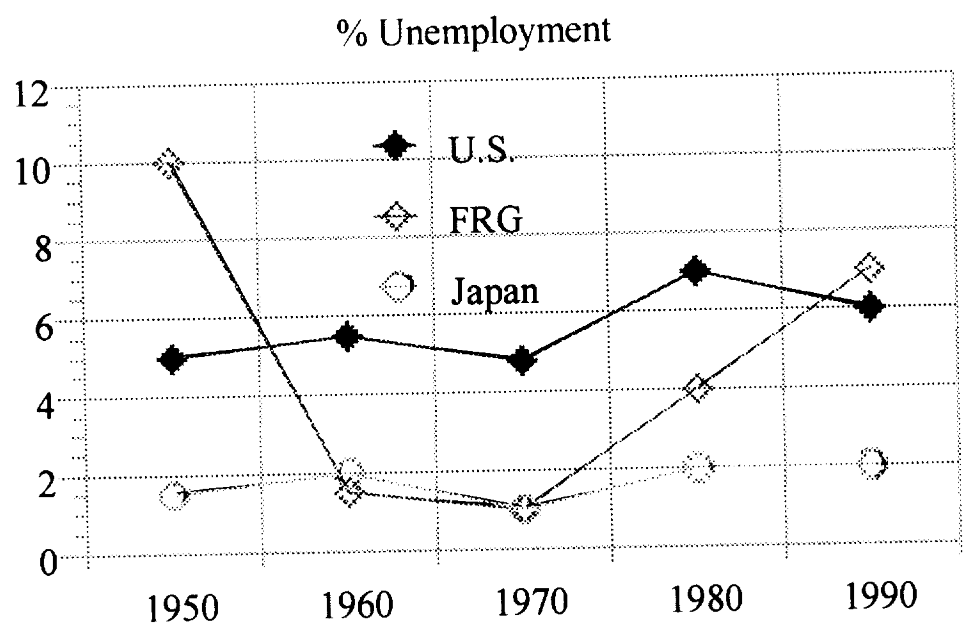
By far, the most common explanation for the use of automated material handling equipment in Japan is the shortage of labor, which is currently severe, with forecasts for a nearly untenable situation. The labor shortage is reflected in the low unemployment rate (Fig. 3.2), long working hours (Fig. 3.3), and rapidly aging work force (Fig. 3.4). The use of automated material handling systems addresses the labor shortage in several ways.

In general, automating a task is a way to create labor by freeing people from non-value added work. While the U.S. views labor as a cost to be minimized, the Japanese seem to view labor as a resource to be optimized. The United States asks, "Given a specific task, what is the lowest annual cost for performing it?" The Japanese ask, "Given a fixed number of people, what is the most value I can add with the best assignment of skills?" The Japanese treat human capital the way we manage financial capital.

Automation is often used to perform the most tedious or physically demanding jobs. Perhaps it is even used, not to eliminate the operator, but merely to assist. This creates a more attractive work environment and makes it easier for a company to compete for labor in a tight market.

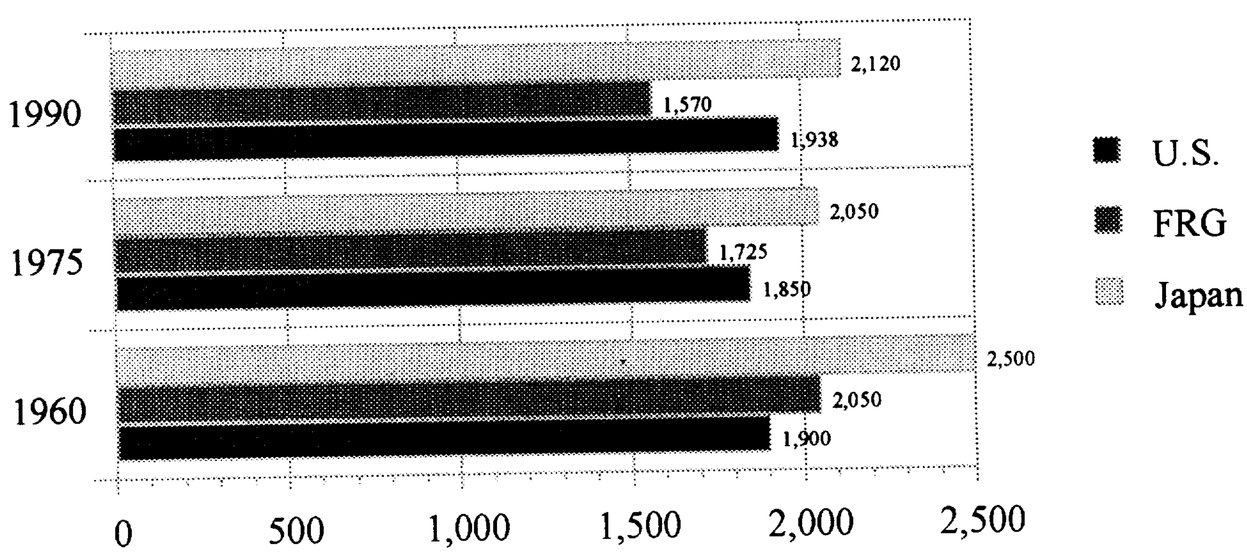
The fact that work is not hard to find, and that technology is used to reduce the effort required by people, makes automation more readily acceptable to the Japanese work force. They see automation as job enhancement and an indication that management cares about people, rather than as a threat to job security.

Most of the labor in the distribution facilities that we visited was classified as part-time. In some instances that meant that a worker worked a standard week, but fewer weeks of the year. In other cases, some workers, usually young women, worked a shorter day during school hours. Both of these approaches are made attractive by a tax law that permits a dependent (presumably a spouse) to earn up to ¥1,000,000 per year without paying normal income taxes.



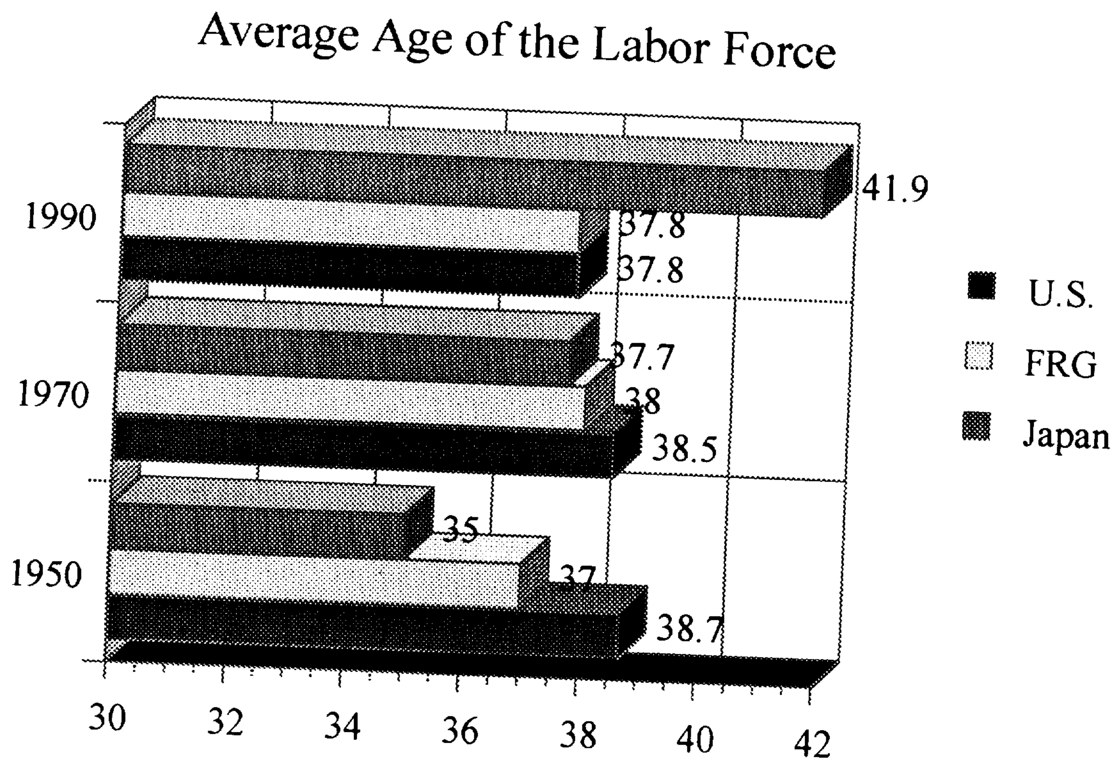
Note: FRG=Federal Republic of Germany

Figure 3.2. Japan's Low Unemployment



Note: FRG=Federal Republic of Germany

Figure 3.3. Average Annual Working Hours in Manufacturing, per Person



Note: FRG=Federal Republic of Germany

Figure 3.4. Japan's Aging Work Force

By providing this flexibility in operation, a Japanese company has access to a larger supply of lower-priced labor. But the penalties show up in additional design requirements for the material handling systems. To accommodate a shorter workday, system hourly throughput capacities must be 50-150 percent higher. To deal with the high work force turnover experienced by employers of part-time workers, jobs must be simplified, easy to learn, and somewhat foolproof to reduce training time and to minimize errors. Many of the electronic order-picking aids were employed to address this issue as much as to improve productivity.

Japanese tend to remain in the work force longer than Americans. The average age of the Japanese worker in 1990 was forty-two compared to thirty-eight in the U.S. At that time, the average age in the U.S. was slowly dropping, while in Japan it was rising rapidly. The best and youngest workers find employment in the more stable and value-adding jobs in manufacturing, while distribution is left with a disproportionate share of older workers. To help them remain productive, ergonomics and simplification through automation become increasingly important in system design and technology development.

Work Style

In addition to the issues of space and population, the Japanese bring a different attitude to the work place. They seem to be more patient than we are, perhaps as a strategy or perhaps just an extension of historical values and character. In addition, they value working together in harmony with other people and with the environment, both natural and man-made.

Teamwork

The Japanese attitude toward teamwork and shared responsibility might affect the level of technology developed or employed in the following ways.

1. As a team, working with nonthreatening interaction, more alternatives may be considered and more issues addressed constructively. The resulting solution is more likely to be the best one or at least one that has unified support. There are no detractors to undermine success.

2. If a failure does occur, it is shared, so that an individual feels less personal exposure and perhaps more willingness to participate in a new venture. The sharing of risk increases the commitment of each team member -- both those within the user company and those who work for the equipment supplier implementing the system. The team will even include members of management who have approved the project.

3. The broad representation of the team provides increased confidence that issues related to future changes in requirements have been identified so that the solution may be considered long-term rather than short-term. This, in turn, has an impact on attitudes toward the length of payback periods.

Continuous Improvement

The Japanese have been praised for having both the desire and the patience to continually enhance a product or system. They strive for improvement not just to attain a certain goal, but also to continue until the product or system is rendered obsolete by a completely new problem statement or solution. By contrast, in the U.S., we value breakthrough thinking and goal attainment. This attitude encourages waiting for a solution that represents a step-function improvement and resting at a plateau after achieving an established objective.

Consequently, our progress is erratic, frequently with very good results but in a somewhat unexpected direction. Theirs is steady and most often focused on a strategic goal.

For example, we have not made really significant changes in the cost and performance of automated storage and retrieval technology since the application of solid-state controls. The Japanese are currently attacking operating speed, reliability, cost and delivery time with results that clearly establish world class standards.

Value of Automation

By itself, without regard to rigorous cost/benefit analysis, automation holds fascination and value for the Japanese. When logistics professionals responded in a survey to rank the factors that characterize system quality, they ranked the level of automation first. In contrast, the U.S. tends to rank it last of the four major criteria (Table 3.3).

Table 3.3
A Contrast in Styles

Factor Rank	Japan	U.S.
1	Level of Automation	Customer Service
2	Info/Control System	Info/Process Integration
3	Info/Process Integration	Info/Control System
4	Customer Service	Level of Automation

Intangible Factors

The United States consistently evaluates capital expenditure decisions and selections of technology alternatives based on costs and benefits that are easy to quantify in monetary terms. Those that are difficult to quantify, or for which data is not readily available, are classified as intangibles. After performing a rigorous economic analysis, intangibles are used as a tie-breaker.

In Japan, the intangibles are frequently in valued areas, such as quality of life and harmony between man and the environment. Designing safe and easy work, providing a light and quiet work place, and creating a system that portrays a positive image of the company all become part of the basic system design requirements. Any alternative that does not include them will not be considered. Because these factors are always included in the initial design, it is then possible to subject them to the continuous improvement process to increase their functionality and to reduce their cost. Meanwhile, the U.S. continues to view them as costly options.

BUSINESS FACTORS

The design requirements that the Japanese impose on material handling systems make them more expensive investments than in the U.S. There are some general business factors present in Japan that enable a capital spending level significantly higher than is available here.

As mentioned earlier, the systems that the JTEC team visited were all relatively new. These systems were planned and approved during a period from two to five years ago. It is particularly important to recognize that business conditions in Japan have changed recently. The same projects might not receive such ready approval today.

Capital Availability and Cost

A large influx of cash from a highly successful export economy and a high personal savings rate combine to provide an abundant supply of capital to invest. Where the U.S. material handling industry is forced to make choices between investment options, often having to forego even good opportunities, Japan seems to have been able to fund them all.

When capital had to be raised from outside the company, it was frequently done with notes or bonds convertible to stock at a fixed price at a future date. When the stock market in Japan was booming, investors were willing to select this option at very low (sometimes almost zero) interest rates with the expectation that they would make a very profitable conversion later. The performance of the Japanese stock market over the past year has burst that bubble. Capital is no longer so available, and when it is, the cost is now at world market rates.

Shareholder Expectations

In the United States, corporate management has responded to large institutional investors who have limited loyalty to any particular holding and expectations of continually high earnings and dividend payouts. This forces management to search for capital investments with very fast payback. In Japan, companies respond to stockholders who traditionally have had great loyalty and are interested in the image and long-term prospects of their investment. Dividend payouts have been a much smaller proportion of earnings (Fig. 3.5). This has permitted Japanese managers to employ longer-term capital investment strategies.

Additionally, during the last several years Japan has enjoyed a growth economy. When the U.S. experienced a similar expansion, domestic capital expenditures were also much higher and made with much less pressure on rapid payback.

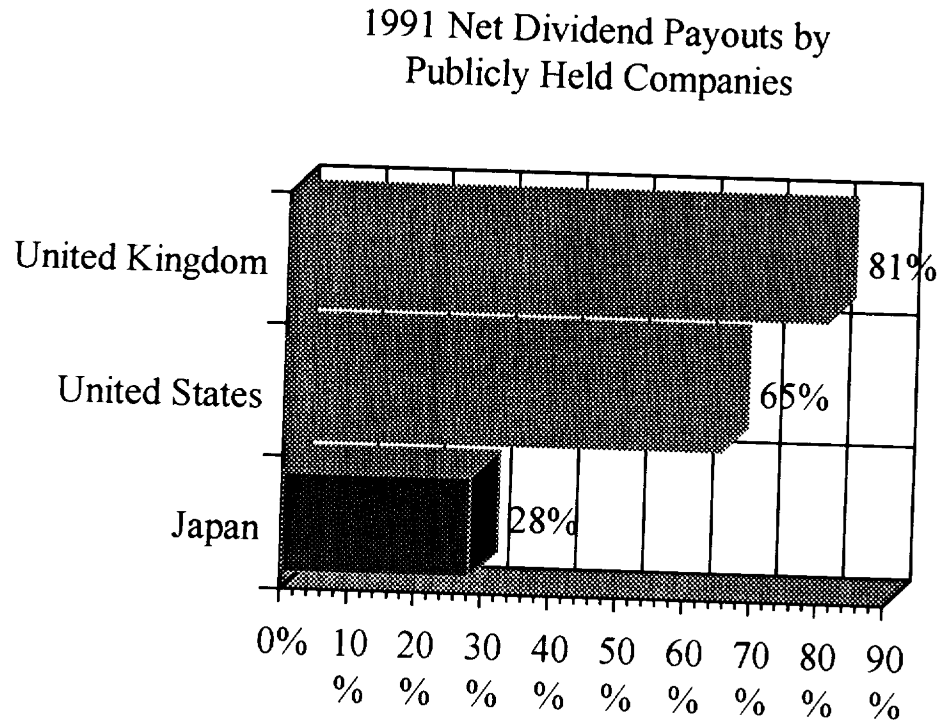


Figure 3.5. High Levels of Capital Availability Make High Levels of Automation Justifiable

Customer-Supplier Relations

Lastly, Japan shows evidence of a stronger customer/supplier relationship than does the U.S. Suppliers are selected for very large projects based on their conceptual solution to a problem, on the ability to meet not only performance but also intangible criteria, and on perceived compatibility with the customer team and its ideals.

After management chooses one supplier to work with, the detailed design is developed and a fair price negotiated. The supplier commitment to provide the best and most reliable system often results in some unplanned expenditures that are absorbed in the price.

The commitment from the customer seems equally strong and long term. The JTEC panel saw systems where components were developed and patented jointly by customer and supplier. Suppliers frequently provided on-site contract maintenance support for large systems, and contracted for modifications and additional systems, even with completely new designs, without going through the selection process again.

Of course, similar productive relationships exist in the United States. However, these close relations appear to be the exception in the U.S. and the norm in Japan.

CHAPTER 4

TECHNOLOGY ASSESSMENT: APPLICATIONS

Edward H. Frazelle

INTRODUCTION

As discussed in Chapter 3, several severe conditions govern the application and development of material handling technology in Japanese warehouses and distribution centers. First, a severe labor shortage -- reflected in low unemployment, long working hours, and aging work force -- implies that material handling system designs must minimize human work content. In addition, younger workers expect a higher quality of life highlighted by increased leisure time, older workers have reduced capabilities, and temporary workers have limited skills. Therefore, material handling systems must create a safe, pleasant, and simple work environment. Second, a severe space shortage -- reflected in high population and industrial densities -- implies that system and facility designs must minimize land-space requirements. Third, just-in-time deliveries to a plethora of small retail outlets served by many wholesalers imply that material handling system designs must have a high throughput capability. Finally, in an economy established on high-quality performance, material handling systems must also achieve high-accuracy performance.

Here we review the effect these requirements have on the application of Japanese material handling technology. The review is organized by the major categories of activities within a warehouse or distribution center: receiving, storage, picking, shipping, and material transport and sortation. Within those major functional areas, the discussion follows the typical degradation of an inbound unit load from full pallet to loose cases to loose items. In each case, a brief application example is described based on one or more of the sites visited by the panel. Greater detail on each site is provided in the appendix. Further discussion concerning most of the 38 equipment types follows in Chapter 5.

RECEIVING: AUTOMATED, DIRECT PUT-AWAY TO STORAGE

The traditional receiving process includes unloading inbound trailers, staging inbound loads, inspecting and checking inbound material, and putting material away in reserve storage locations. In direct put-away systems, the staging and inspection operations are eliminated. Hence, the time, space, and labor associated with those operations is eliminated. The most advanced logistics operations are characterized by automated, direct put-away to storage and are described below. The material handling technologies that facilitate direct put-away include trailers equipped with in-floor rollers, extendable conveyors, and automated unloading devices.

Full Pallet Receiving

Roller-bed Trailers. At Kao's Iwatsuki City distribution center, trailer beds are equipped with in-floor rollers to permit the moving of inbound pallet loads from Kao manufacturing sites from inbound trailers onto powered roller conveyors for immediate transport into a large unit load AS/RS (Fig. 4.1 and 4.2).

Loose Case Receiving

Extendable Conveyors. At Mutow, a separate prepackaging facility is in place to pack inbound merchandise into standard case sizes. The standard cases are floor-stacked and transported to the receiving docks at the main distribution center. At receiving, an extendable conveyor allows direct movement of inbound cases from the trailer to powered roller conveyor to be put into a mini-load AS/RS (Fig. 4.3).

In-floor Roller and Ball Transfer Conveyor. At Sun Distribution Center, floor-stacked cases are palletized onto slip sheets at the receiving point. The entire dock area is covered with in-floor roller conveyor and ball transfer devices to permit immediate movement of the palletized cases to a storage area on the third floor (Fig. 4.4).

Loose Item Receiving

Extendable Conveyor. At Shiseido's Fukaya distribution center, loose items are received in collapsible totes from Shiseido manufacturing sites. The inbound storage totes are offloaded onto an extendable conveyor that feeds a powered roller conveyor for direct input into a mini-load AS/RS (Fig. 4.5).

Figure 4.1. (Left) Roller-bed Trailers-1 (Kao)

Figure 4.2. (Below) Roller-bed Trailers-2 (Kao)

Figure 4.3. Extendable Conveyor (Mutow)

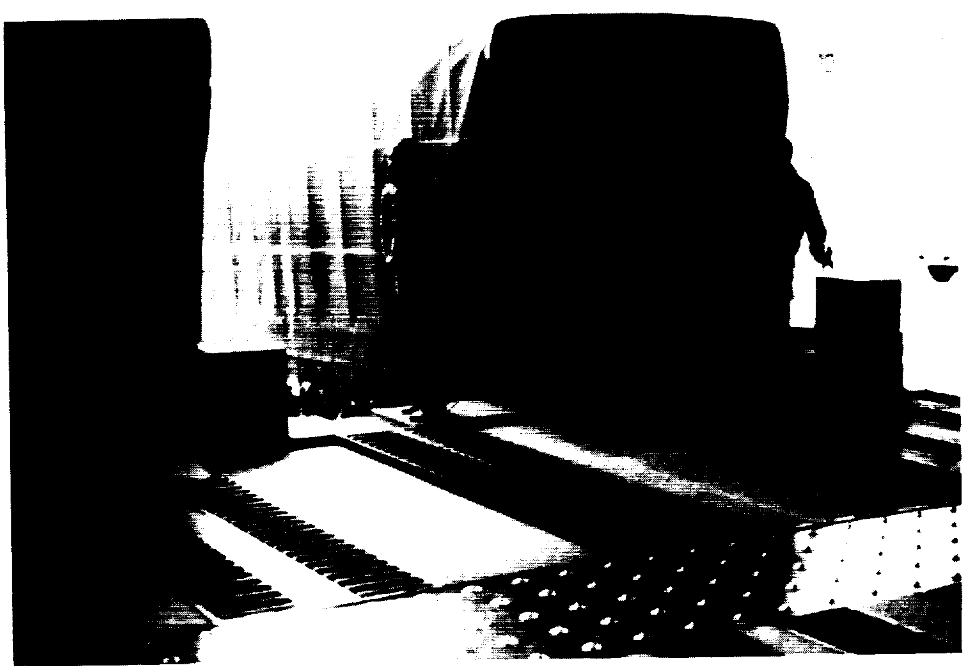


Figure 4.4. Ball Transfer Conveyor (Sun Bird)

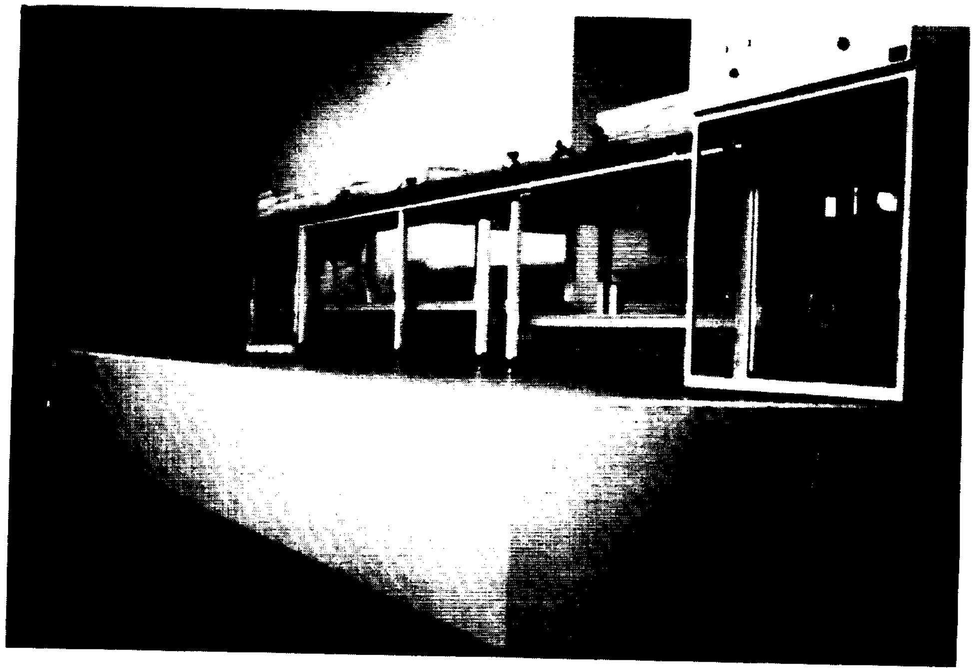


Figure 4.5. Extendable Conveyor (Fukaya)

STORAGE: SIMULTANEOUS HIGH DENSITY AND THROUGHPUT

With a requirement to simultaneously minimize land/space requirements and maximize throughput capacity, storage systems must break away from the historical tradeoff of storage density for product accessibility. A variety of systems have been applied to successfully make the breakthrough, including twin-shuttle automated storage/retrieval systems, multicrane AS/RS aisles, rotary-rack carousels, and high-velocity input/output systems for AS/RS.

Full Pallet Storage

Twin-Shuttle, Multi-Crane AS/RS Aisles. At Sapporo's Chiba brewery, a 10-aisle unit load AS/RS (Hitachi) houses 25,100 plastic pallets (5.5 days' supply). Each aisle is equipped with 2 twin-shuttle storage/retrieval machines (Fig. 4.6), each operating at a maximum horizontal travel speed of 480 feet per minute and an average cycle time of 95 seconds (25 seconds per pallet store or retrieve on a quad-command cycle). As a result, the maximum throughput per machine is 120 transactions per hour; the maximum throughput capacity per aisle is 240 transactions per hour; and the maximum system capacity is 3,000 pallets per hour. Each end of the system is serviced by a 2-level cart-on-track conveyor operating at a maximum travel speed of 225 feet per minute. Each cart can accommodate 2 pallets.

Figure 4.6. Multi-Crane AS/RS Aisles (Sapporo)

At Banyu's Tokyo pharmaceutical distribution center, a three-aisle multi-purpose unit load AS/RS serves three floors in the distribution center. The AS/RS transports pallets to the third floor, which is dedicated to 22 permanent floor-level pallet picking positions, 21 fixed positions for case picking high-volume items, and one spare position. Each picking position is backed by two pallet reserve positions on a single-deep selective rack. A small, twin-shuttle S/R (storage/retrieval) machine manages the storage, retrieval, and sorting of full and empty pallets for case picking.

Conventional AS/RS. At Kao, a 17-aisle, 100 feet tall AS/RS is used for pallet storage and retrieval (IHI). The AS/RS has a storage capacity of 600,000 cases (a two-week supply), and also serves as a staging system for outbound pallet loads. The input/output system is a conventional pallet roller and chain conveyor.

At Toyota Colnet, an AS/RS is used to store and retrieve new automobiles. The input/output system is a car-on-track conveyor (Fig. 4.7). The panel also saw conventional pallet AS/RS systems at Suntory's whiskey distribution center and at Shiseido's Fukaya distribution center.

Mobile Storage. At Sapporo (Fig. 4.8) and Kao (Fig. 4.9), mobile pallet rack systems house slow-moving items with almost no aisle space to maximize space utilization.

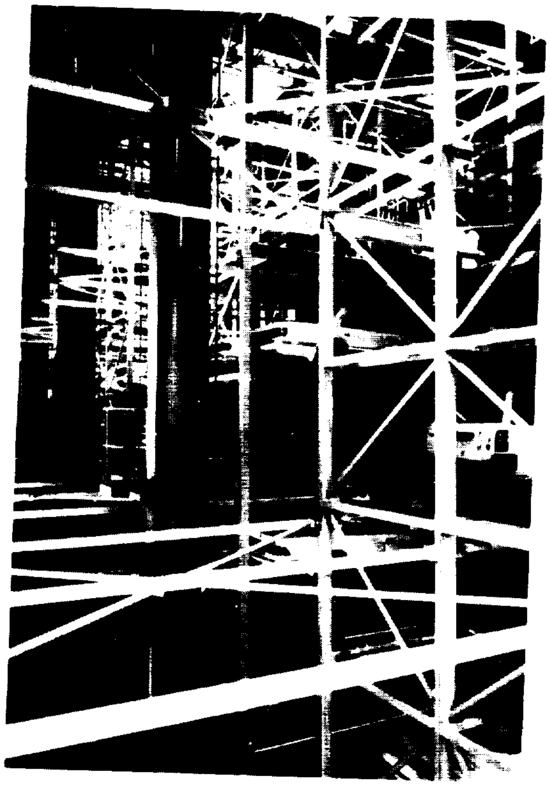


Figure 4.7. Conventional AS/RS
(Colnet)

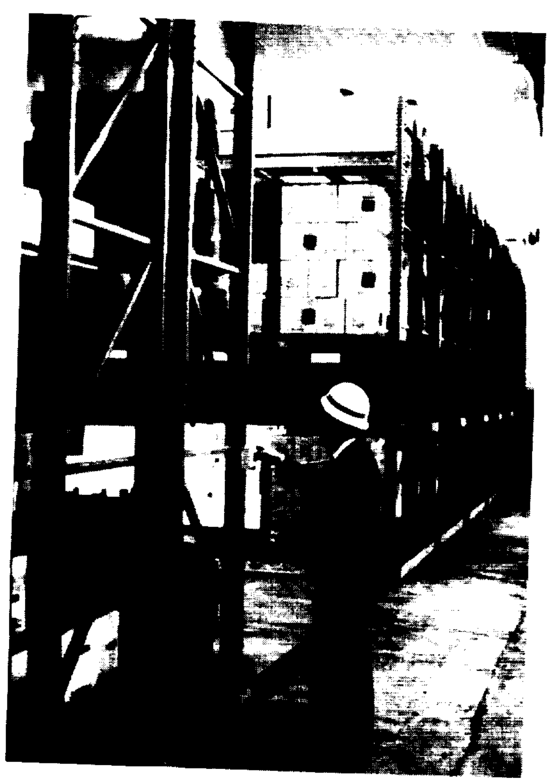


Figure 4.8. Mobile Storage
(Sapporo)

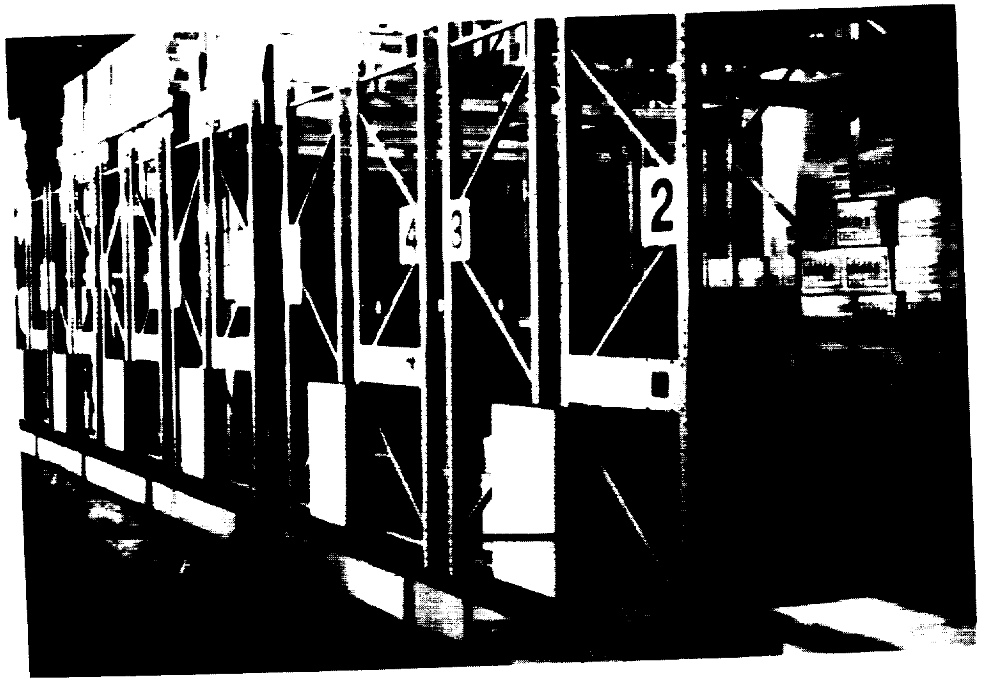


Figure 4.9. Mobile Storage (Kao)

Loose Case Storage

Mobile Storage. At Sun Bird's franchise logistics center, 70 percent of the floor space is covered with in-floor roller conveyor and ball transfers. Cases are stored on slave pallets that are easily maneuvered on the in-floor conveyor. As a result, only a small portion of the floor space needs to be devoted to aisle space, and product access is not sacrificed (Fig. 4.10).

Loose Item Storage

Multi-crane AS/RS Aisles. At Shiseido Fukaya, a tote-handling AS/RS is used for loose item storage. The system is unique in that a shuttle car is provided for every three levels of storage in every aisle. A large mast services each aisle to transfer totes to/from delivery/takeaway conveyor lines. The storage capacity is 29,000 totes, and the throughput capacity is 2,500 totes per hour (Fig. 4.11).

Twin-Shuttle AS/RS. At Shiseido's Nagoya logistics center, a large twin-shuttle micro-load AS/RS is used for loose item storage (Fig. 4.12 and 4.13).

At Mutow's Hammamatsu mail order distribution center, a twin-shuttle mini-load AS/RS is used to store standard size cases for broken case picking from the back side of the AS/RS aisle (Fig. 4.14 and 4.15).

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Figure 4.10. Mobile Storage
(Sun Bird)

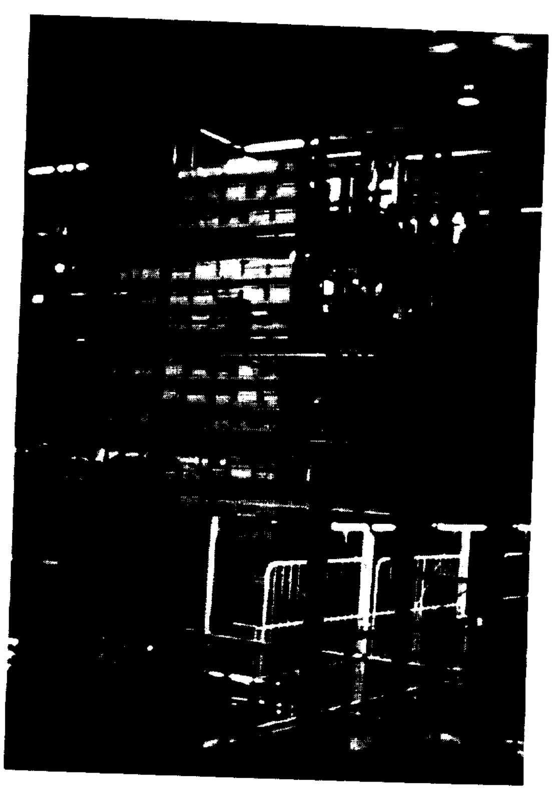

Figure 4.11. Multicrane AS/RS Aisles
(Fukaya)

Figure 4.12. (Left) Twin-Shuttl
AS/RS-1 (Nagoya)

Figure 4.13. (Right) Twin-Shuttle
AS/RS-2 (Nagoya)

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Figure 4.14. (Left) Twin-Shuttle AS/RS-3 (Mutow)

Figure 4.15. (Below) Twin-Shuttle AS/RS-4 (Mutow)

Rotary Rack Carousel. At Ohki's Tokyo logistics center, a rotary rack carousel is used for loose item storage in tote pan containers. The input/output system is Okamura's Laddermatic conveyor. When fully extended at the top of the rotary rack, the Laddermatic acts as a conventional powered roller conveyor. However, the Laddermatic can swing down to accept a tote from each level of the rotary rack by interfacing with a small outbound conveyor spur servicing each level of the rotary rack (Fig. 4.16).

PICKING: FAST, ACCURATE, SIMPLE, AND AUTOMATED

Picking typically encompasses the extraction of material from storage locations to satisfy customer orders and the replenishment of depleted picking locations. It is the most labor-intensive, error-prone, and time-critical activity in a typical warehouse or distribution center. Hence, it has been the focal point for the application of a wide variety of automated systems, including multiload vehicles, tier picking, light aids, intelligent picking vehicles, batch pick for direct sorter induction, and dynamic pick line configuration.

Full Pallet Picking

Other than the unit load AS/RS operations described above, and conventional forklift operations, the only exceptional pallet picking operation was observed at Suntory's Kisogawa Plant beer distribution center. There, lift trucks are configured to handle four pallets at a time.

Loose Case Picking

Automated Tier Picking. At Kao's Iwatsuki City distribution center, pallets flow out of an AS/RS to a series of automated tier (or layer) pickers, essentially depalletizers. The tier pickers operate at a rate of 1,000 cases per hour and singulate cases onto a carton takeaway conveyor for transport to (1) sortation/accumulation lanes for order fulfillment or (2) an automated carton flow rack replenisher for loose case storage (Fig. 4.17-4.20).

At Suntory's Kisogawa Plant beer and wine distribution center, a small single-aisle pallet buffer AS/RS is dynamically loaded to feed an adjacent tier picker. To build the full-tier portion of an order, pallets flow from the pallet AS/RS to the tier picker, where the appropriate number of tiers are removed and transported across the top of the tier picker to a waiting shipping pallet. The storage pallet is then returned to the AS/RS. If there is only one SKU on the order, the pick-to pallet is advanced on pallet conveyor to a pick-up-and-deposit (P&D) station. If there are multiple SKUs on the order, the successive storage pallets are layered until the full-tier portion of

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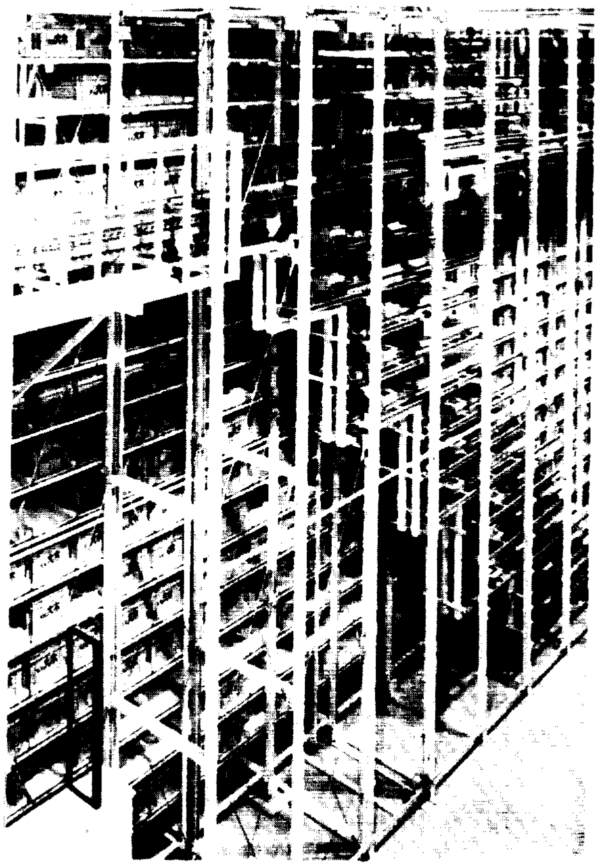


Figure 4.16. (Left) Rotary Rack Carousel (Ohki)

Figure 4.17. (Right) Automated Tier Picking-1 (Kao)

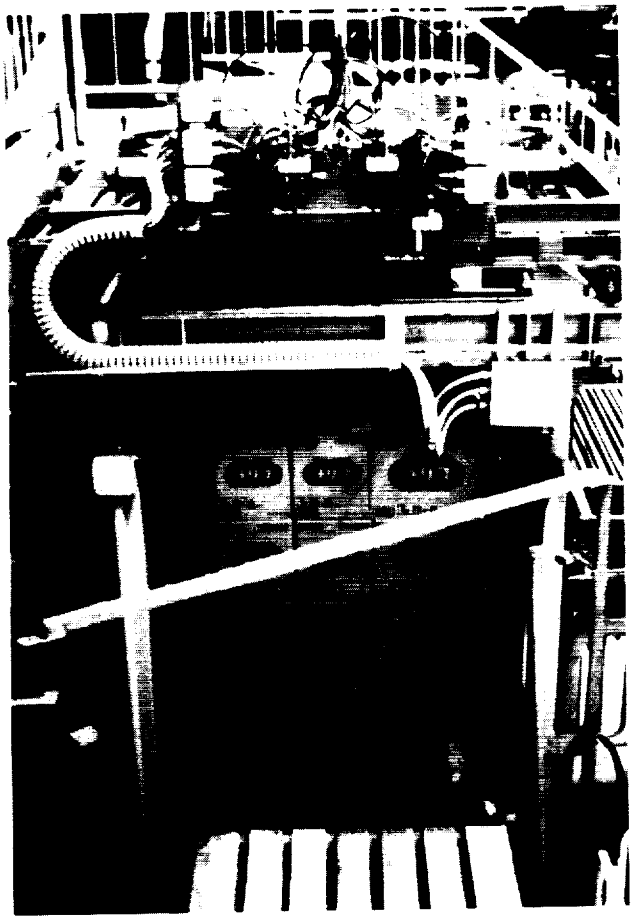
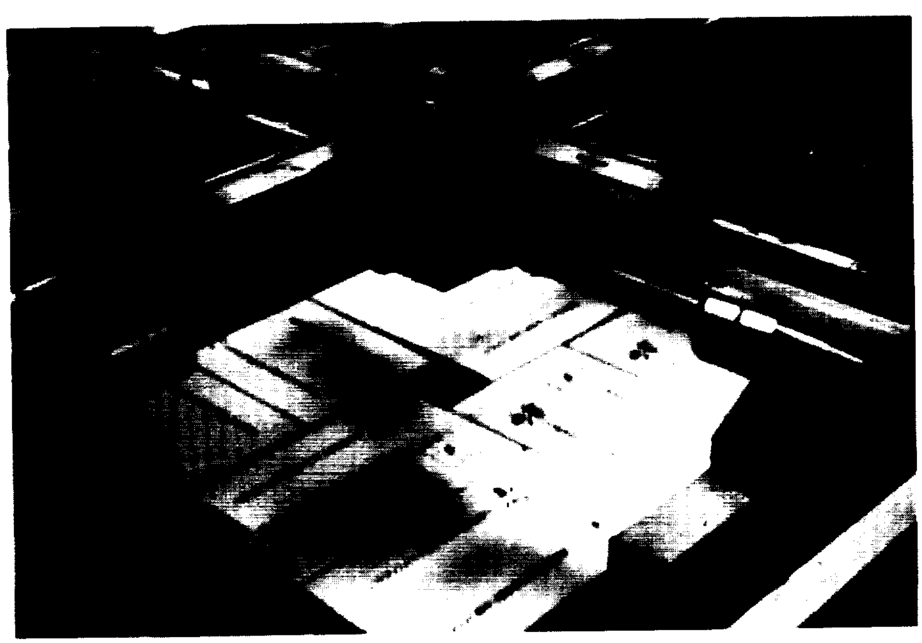


Figure 4.18. (Left) Automated Tier Picking-2 (Kao)

Figure 4.19. (Below) Automated Tier Picking-3 (Kao)



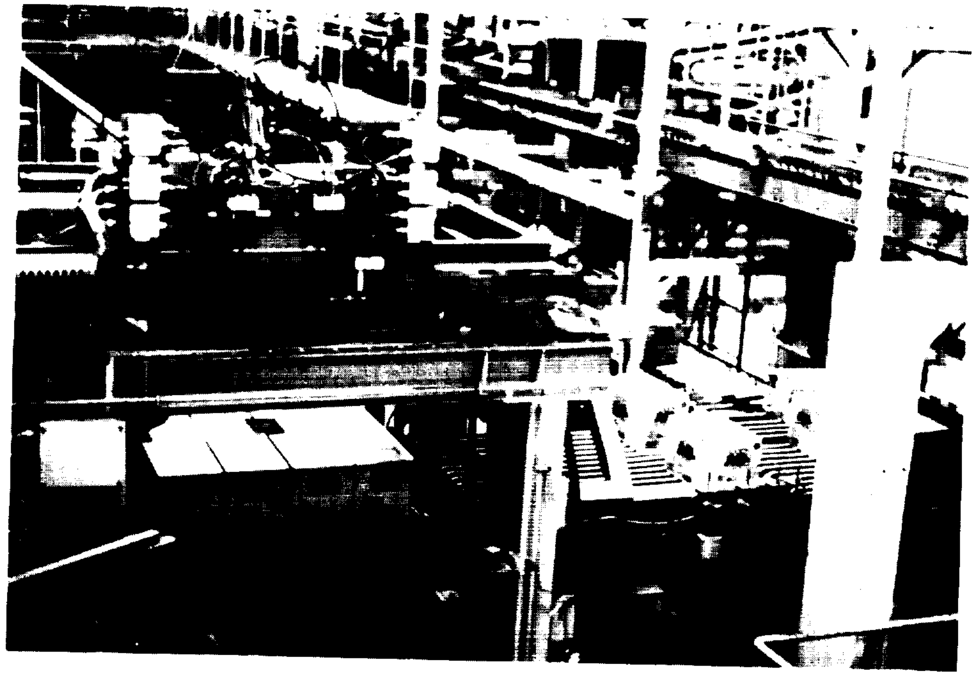


Figure 4.20. Automated Tier Picking-4 (Kao)

the order is complete. The loose case portion of the order is picked from floor-level rack positions with lift trucks. Truck mounted radio frequency terminals are used to direct the loose case picking. (Fig. 4.21-4.23)

Automated Loose Case Picking. At Kao, an AS/RS machine has been retrofitted with telescoping conveyor to allow automatic extraction of single cases from the gravity flow rack. The AS/RS can extract up to 500 cases per hour from the flow rack. A similar device replenishes the flow rack lanes (Fig. 4.24 and 4.25).

Case Pick-to-Light. At Suntory's whiskey distribution center, the case pick-to-light operation takes an unusual twist. In addition to pick-to-light displays over each pallet-picking position, there is also a conventional incandescent lamp (or beacon) with four colored lenses and four bulbs mounted at the end of each rack aisle at about three meters height. The operator receives an order which is color-coded (one of four colors for one of four operators). The operator is then directed through the order as follows: The corresponding colored lens in each end-of-aisle beacon is illuminated by the local computer when the operator receives the color-coded order. The operator then chooses the aisles by looking for the illuminated beacons. After making the first pick in an aisle, the lamp is extinguished automatically. Note that at any one time it is possible for all four colored lenses in a given beacon to be illuminated, indicating that all four operators have orders requiring picks in that aisle. Once in an aisle, an operator is directed to a pick location by looking for illuminated

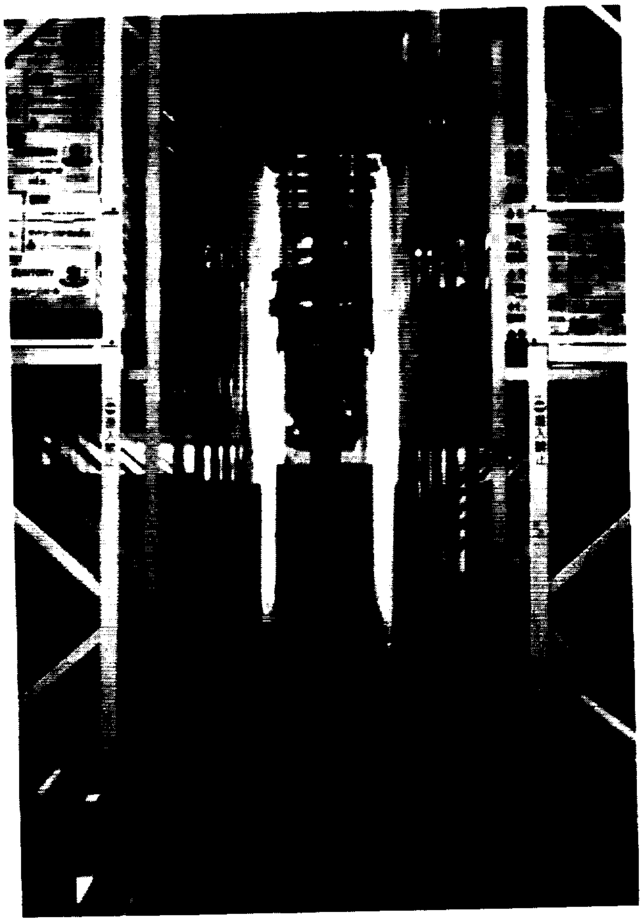


Figure 4.21. (Left) Loose Case Picking-1 (Suntory)

Figure 4.22. (Below) Loose Case Picking-2 (Suntory)

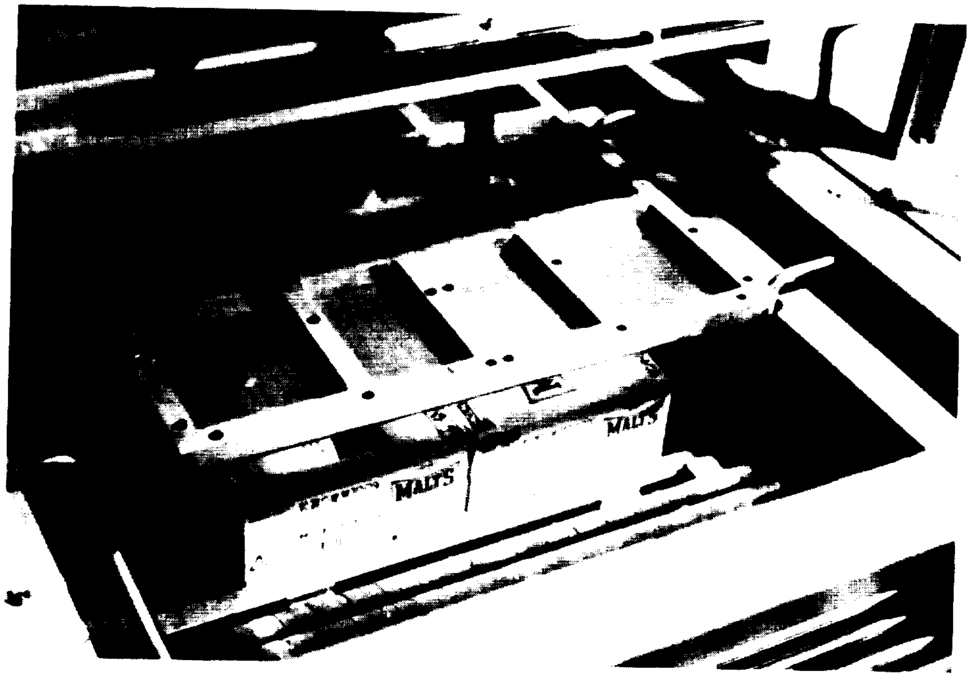
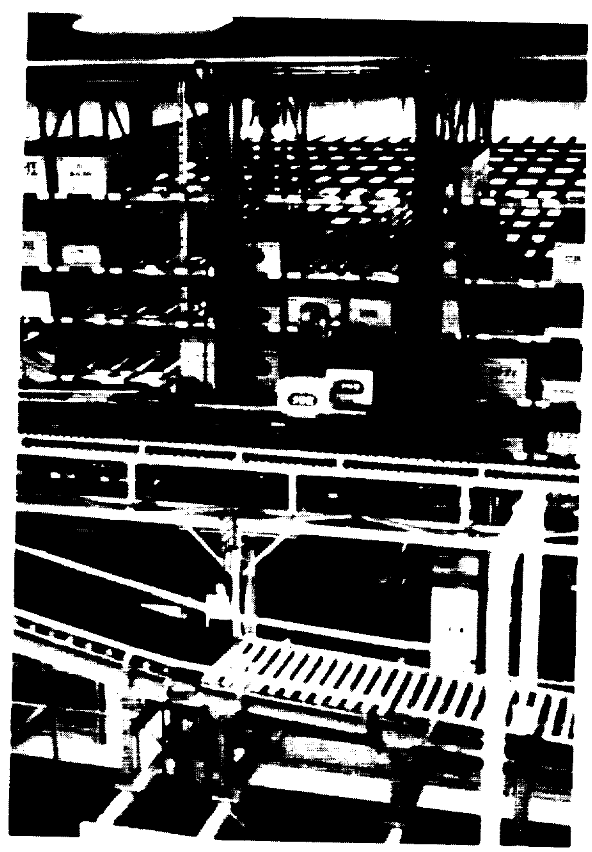


Figure 4.23. (Above) Loose Case Picking-3 (Suntory)

Figure 4.24. (Right) Automated Loose Case Picking-1 (Kao)



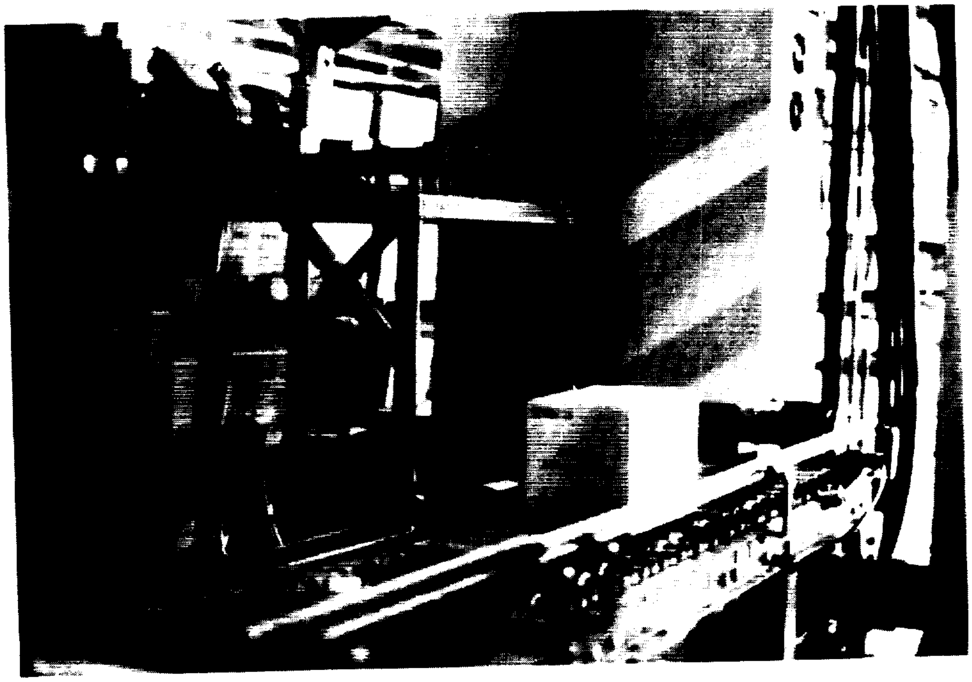


Figure 4.25. Automated Loose Case Picking-2 (Kao)

pick-to-light displays. Again, each pick-to-light display has four small colored bulbs, corresponding to each operator's order color. Attached and hanging from each display unit are four short chains (e.g., desk lamp chains), each with a colored pull tag. On stopping at a lighted display, the operator pulls the appropriate (color-coded) chain, and the item numbers and quantity to pick appear on the LED (light-emitting diode). After picking the correct item and quantity, the operator again pulls the chain to clear the display. The operator proceeds down the aisle, and from aisle to aisle in this manner until the order is completed. Orders are then manually consolidated on a pallet for subsequent automatic transfer to the AS/RS on the first floor.

At Shiseido's Nagoya cosmetics distribution center (Fig. 4.26) and Banyu's Tokyo pharmaceutical distribution center, case picking locations have lighted displays to direct the case picking process.

Loose Item Picking

Light Aids. At Pola's Shizuoka cosmetics distribution center, split case picking of fast-moving items from gravity flow rack is facilitated by computerized pick directors and pick-to-light displays at each picking face. Picking and flow down the picking line is highly synchronized with electronic, push-button interlocks at both the picking face and alongside the conveyor, making picking errors all but impossible.

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Figure 4.26. Case Pick-to-Light (Nagoya)

Figure 4.27. Light Aids-1 (Kao)

At Kao's Iwatsuki City distribution center, broken case picking is organized by waves of order batches. Orders are picked into totes. Batches of five orders/totes pass through a series of picking stations. Each picking station or zone consists of a bay of gravity flow racks housing twelve items. Each flow lane has a light display to indicate the item and quantity that should be selected. Once the quantity has been selected, the light displays in front of the batch of totes direct the order picker to deposit the proper quantity into each tote. At the end of each wave, the light on each lane is illuminated to record the number of units that should remain in the front case. This permits a cycle count at the end of each wave (Fig. 4.27). Light-aided picking systems are also in place at Ohki's Tokyo wholesale drug distribution center (Fig. 4.28) and Sapporo's Chiba beer distribution center (DC).

Intelligent Picking Vehicles. At Shiseido's Nagoya distribution center, computer-generated efficient picking tours of a forward picking area (shelving and flow rack) are created overnight and stored on smart cards. When a smart card is inserted into an intelligent picking vehicle (IPV), an on-board microprocessor illuminates a minimum distance picking tour on a lighted map of the warehouse on the front of the picking cart. As the vehicle traverses the picking aisles, it communicates via infrared signals with the storage locations to illuminate a picking display if it is included on the picking tour. Once the picking display is illuminated, a light below the divider on the cart containing the order illuminates to direct the sortation. Other than the on-board microprocessor and infrared communication capability, the carts are simple, light, manual push carts equipped with tote pans and moveable dividers for order sortation. The picking rate ranges from 120 to 140 lines per hour with picking accuracy at 99.998 percent (Fig. 4.29).

At Pola's Shizuoka cosmetics distribution center, synchronized orders are down-linked to a local personal computer (PC) in the slow-moving, bin shelving picking zone. A picker, ready for the next picking cycle, inserts an IC Ram (random access memory) card into the PC. The PC downloads the picking instruction to the card. The order picker inserts the card into a reader on the picking cart. The cart is equipped with a controller and small video display panel. The panel first displays a layout of the entire bin shelving area, highlighting the shelving faces where picks are to take place. The picker can then choose to begin at any aisle he or she wishes. As the cart enters an aisle, infrared sensors on the cart detect the aisle; the video display immediately changes to show a blown up picture of the aisle. The picking faces and the bins that are ready for picking are highlighted with correct quantities shown for each order. Each cart is equipped to handle 8 orders per order cycle (i.e., 8 bins per cart). Successive video displays and pick-to-light displays (on the shelving and cart bins) allow the picker to progress through the picking cycle quickly and virtually error-free. The system's reported accuracy rate of 4 errors per 1,000,000 picks is achieved with essentially unskilled labor.

Dynamic Pick Line Configurations. At Mutow's Hammamatsu distribution center, a 34,000-position case-handling AS/RS (essentially a mini-load AS/RS) serves as a case storage device and as a forward picking system. Each mini-load aisle is separated by a three-level mezzanine picking aisle in which a conventional wave/zone pick takes place. Overnight, the AS/RS reconfigures the picking location to insure that a majority of picks are at or near waist height and that all of the locations are properly stocked (Figs. 4.3 and 4.14).

Figure 4.28. (Left) Light Aids-2 (Ohki)

Figure 4.29. (Right) Intelligent Picking Vehicles

Direct Sorter Induction - Automated Material Transport. At Shiseido's Fukaya cosmetics distribution center, storage containers are transported on roller conveyor from a mini-load AS/RS to sorter induction stations. Each induction station is staffed with two operators. Directed by a light display, one operator removes the indicated number of units from the storage tote for the current wave and places the units next to the induction operator. If the storage container is empty, the empty tote is placed on an empty tote takeaway conveyor running just overhead. If the inventory in the storage container is not depleted, the tote is slid onto an adjacent takeaway conveyor for return to the mini-load AS/RS. The induction operator's responsibility is to properly orient the unit for bar code reading and sorter induction. A notch is cut into the workstation to help the operator orient the unit. Order integrity is established by a cross-belt sorter (Fig. 4.30-4.32).

Direct Sorter Induction - Wave Picking. At Nippon Shuppan's Tokyo book DC, order pickers manually pick and transport loose paperback books to sorting induction stations. In one sorting system, Tsubakimoto's one-of-a-kind Multisorter, induction is initiated with an OCR read on one book in the batch. The other sorting systems are conventional tilt-tray sorting systems. At one the induction is via voice recognition, the other via keyboard encoding (Fig. 4.33-4.37).

At Sun Bird's Chiba apparel DC, order pickers manually pick and transport full cases to manual sorting induction stations. Units are bar code inducted onto a tilt-tray sorting system with outbound lanes for each retail store in the current wave (Fig. 4.38-4.41).

At Mutow's Hammamatsu mail order DC, order pickers manually pick loose items from the rear of a mini-load AS/RS and place them on a large rolling cart. At the end of a pass-through zone, the cart's contents are dumped into lanes for formal induction into a cross-belt sorter (Fig. 4.42).

Light and Sound-Aided Replenishment. At Pola's cosmetics distribution center, the replenishment face of each gravity-flow rack bay is equipped with a light display. When a lane in the bay is near empty, the controlling computer illuminates the light and triggers recorded music to signal replenishment operators. Using push buttons, the replenishment operator informs the computer that the replenishment has been completed.

At Toyota's Kamigo Vanning Center, a light is provided on the back of each stocking point along a kitting line to show when an item needs to be replaced along the line. Replenishment operators are signaled by the light's illumination and recorded music (Fig. 4.43).

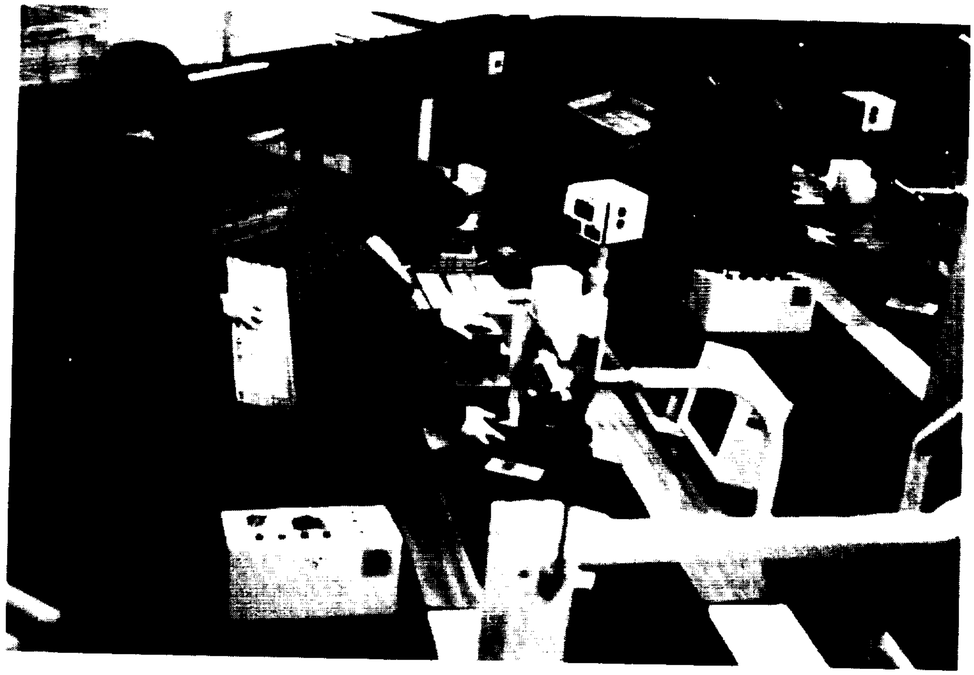


Figure 4.30. Automated Material Transport-1 (Fukaya)

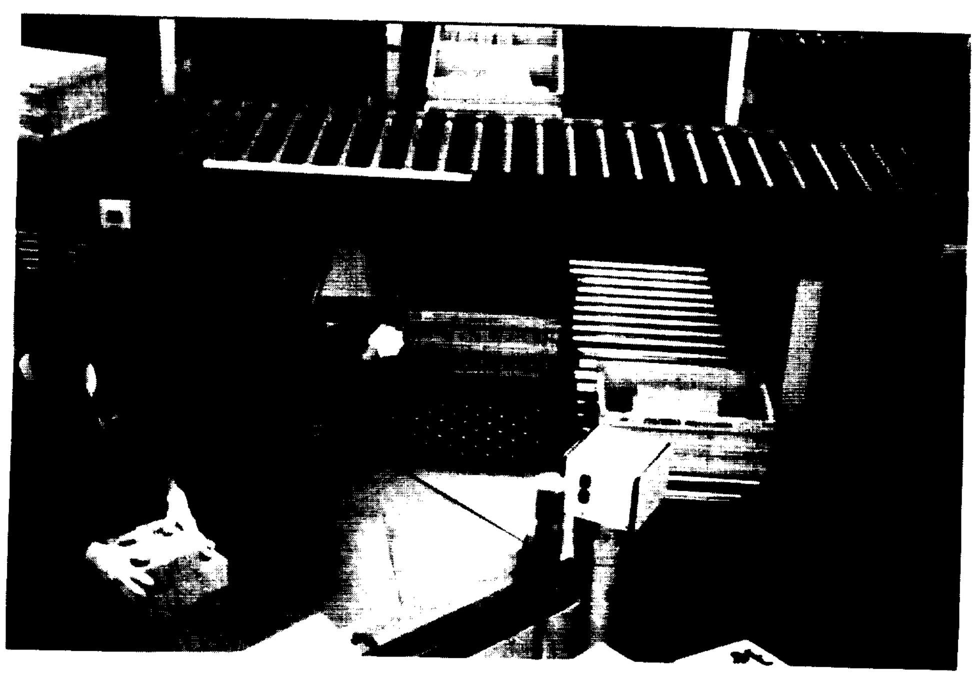


Figure 4.31. Automated Material Transport-2 (Fukaya)

Figure 4.32. Automated Material Transport-3 (Fukaya)

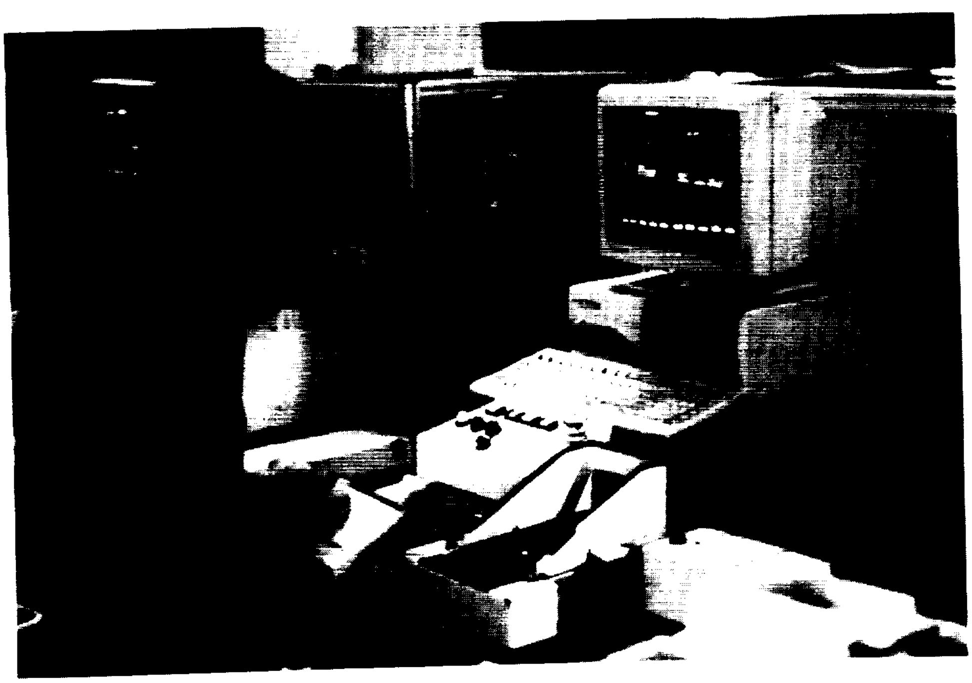


Figure 4.33. Wave Picking-1 (Nippon)

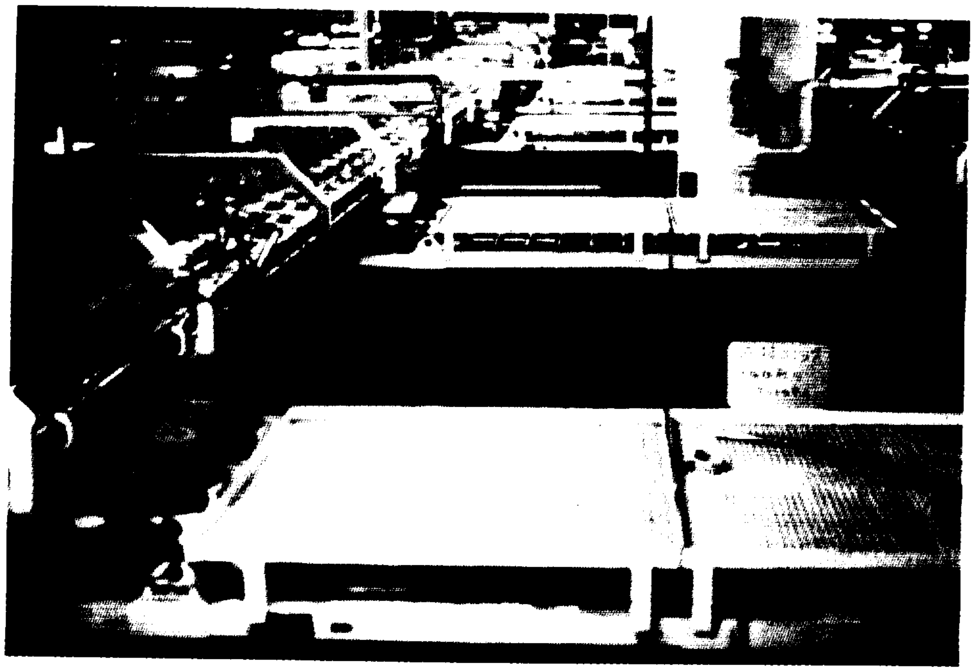


Figure 4.34. (Above) Wave Picking-2 (Nippon)

Figure 4.35. (Left) Wave Picking-3 (Nippon)

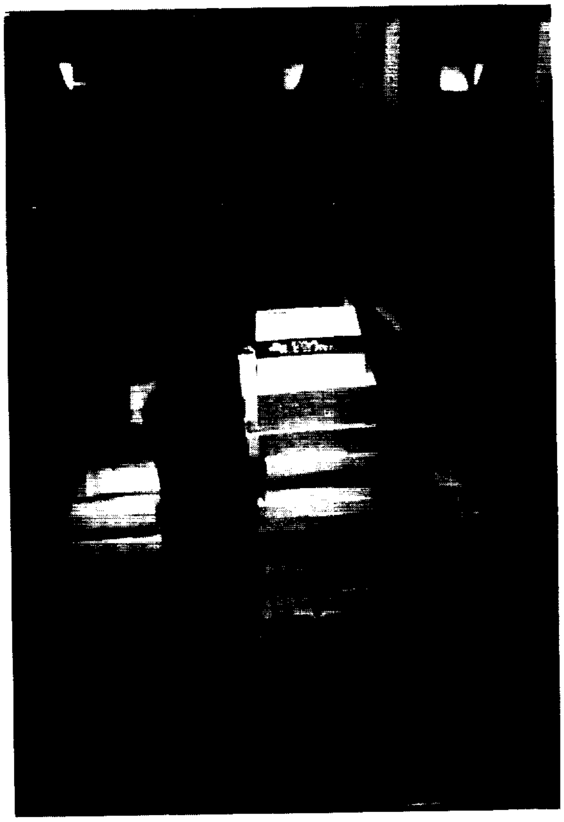
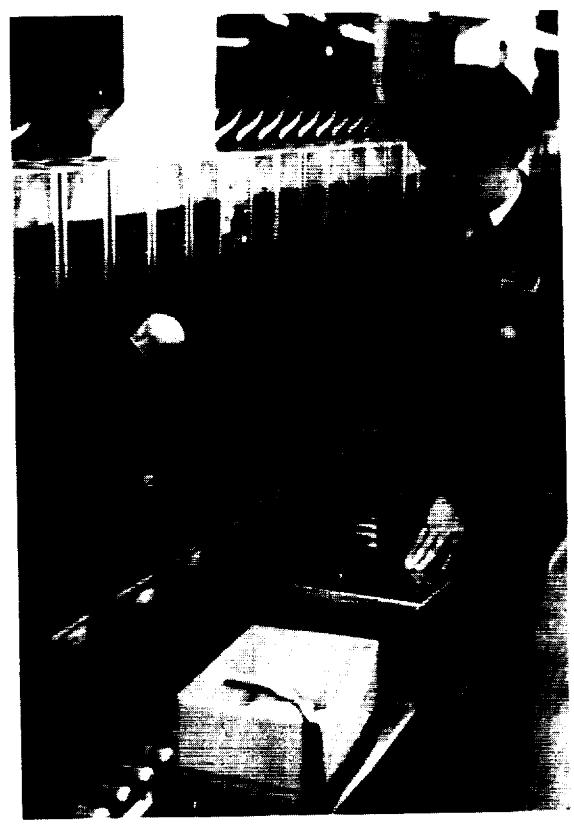


Figure 4.36. (Left) Wave Picking-4 (Nippon)

Figure 4.37. (Below) Wave Picking-5 (Nippon)



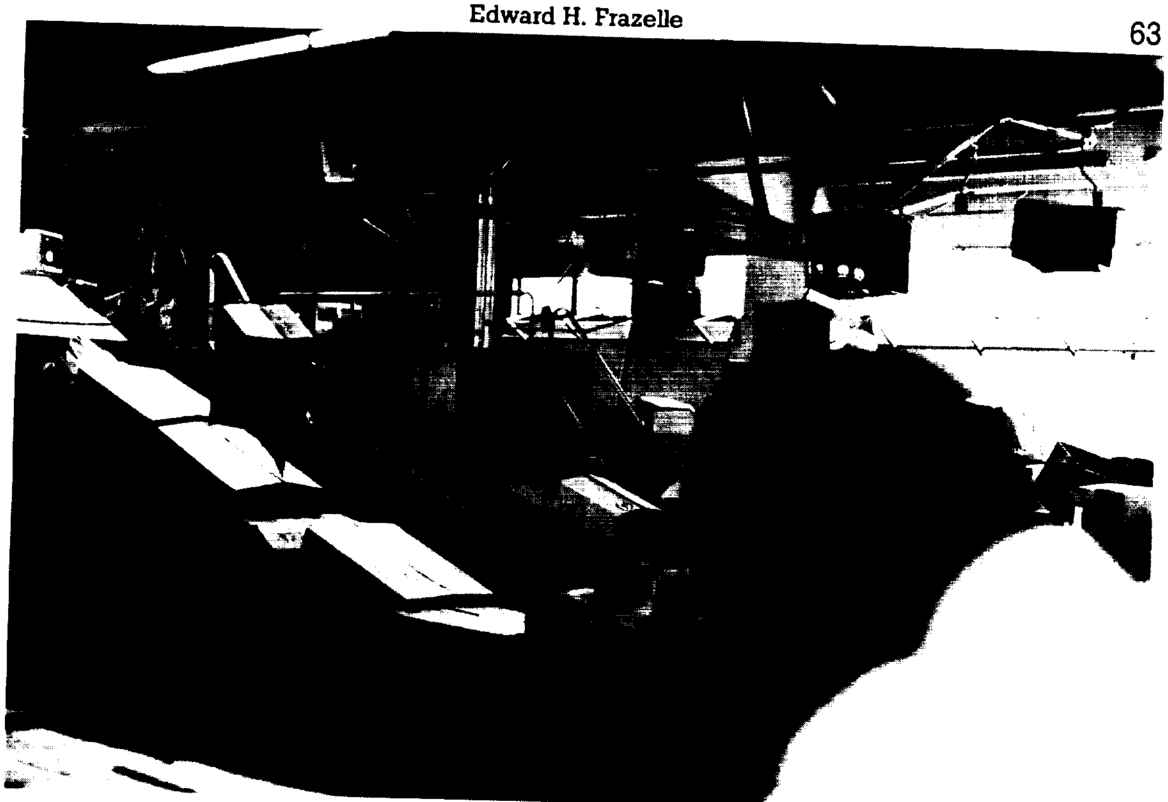


Figure 4.38. Wave Picking-6 (Sun Bird)

Figure 4.39. Wave Picking-7 (Sun Bird)

Figure 4.40. Wave Picking-8 (Sun Bird)

Figure 4.41. Wave Picking-9 (Sun Bird)

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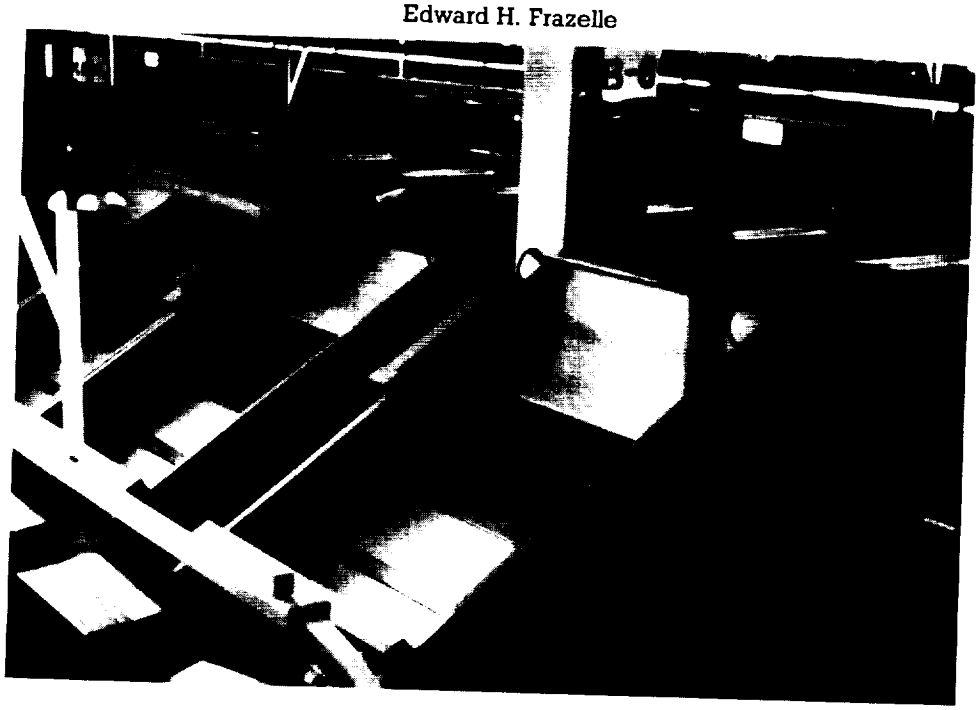

Figure 4.42. Wave Picking-10 (Mutow)

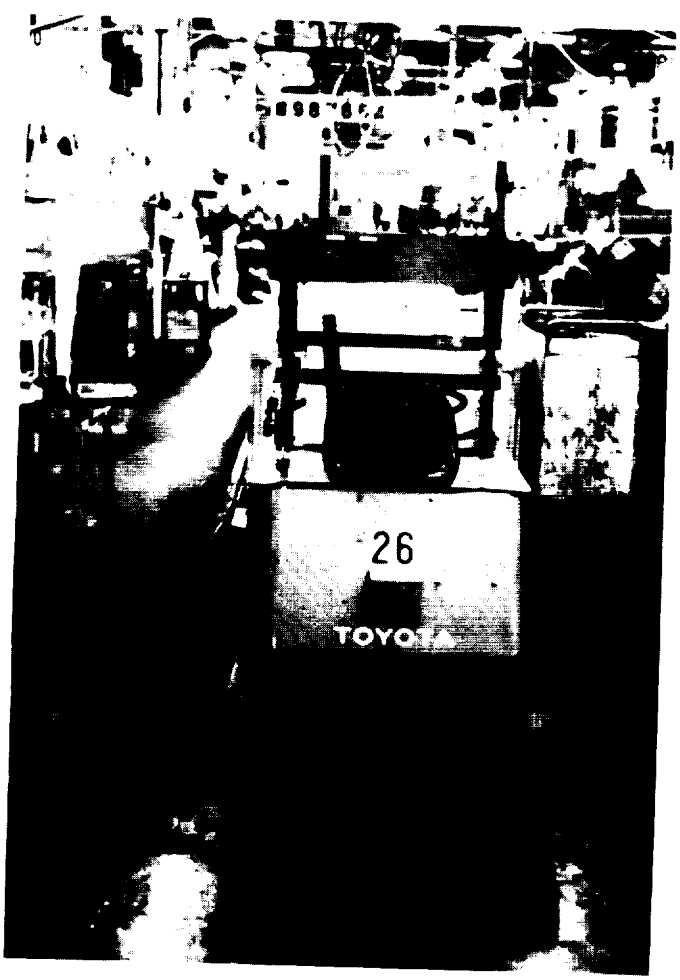

Figure 4.43. (Left) Light and Sound Aided Replenishment (KVG)

SHIPPING: AUTOMATED DIRECT LOADING

Shipping typically encompasses the accumulation, consolidation, staging, and loading of outbound orders. Shipping is another space and labor-intensive function in a distribution center. However, through direct loading of outbound trailers, the staging activity and the associated space, labor, and time are eliminated. The labor content in the remaining shipping activity, trailer loading, can also be minimized through automated forklifts and conveyors that extend into outbound trailers. When the staging activity cannot be eliminated, space requirements can be minimized through rack systems.

Pallets

Automated Forklifts. At Sapporo's Chiba brewery, two automated trailer loaders are used for loading outbound side-loaded trailers. Each loader is equipped with nine sets of two-deep forks to allow a single loader transaction to handle the full trailer of 18 pallet loads. Each loader is fed with pallet conveyor and, at 2.5 minutes per trailer, has a capacity of 24 trailers or 432 pallets per hour (Fig. 4.44 and 4.45).

At Toyota's Kamigo Vanning Center, a conventional counterbalance forklift has been retrofitted to act as an automated guided vehicle for backend trailer loading. A pallet chain conveyor advances a pallet to a position directly in front of the stationary vehicle's forks. The vehicle moves forward, lifts the load, and advances into the back of the trailer. The vehicle is guided with the help of a guide rail that is flush with the trailer wall and extends several feet outside the vehicle.

Pallet Conveyor. At Kao's Iwatsuki City logistics center, loads are transported from staging/consolidation in an AS/RS on a pallet conveyor that interfaces with an in-floor pallet conveyor on outbound trailers for direct trailer loading (Fig. 4.46).

AS/RS Staging. If outbound loads must be staged, high-density storage and throughput are desirable. An AS/RS is used for outbound load staging and order consolidation at Kao and Suntory's whiskey distribution center.

Loose Items in Cases or Totes

Extendable Conveyor. Just as a pallet conveyor can be extended into outbound trailers for direct trailer loading, a tote or case conveyor (skate wheel or telescoping) can be extended from packing lanes into the back of an outbound trailer to minimize manual handling of cases and totes. An extendable skate wheel (or accordion) conveyor is in place at Shiseido's Fukaya cosmetics distribution center, at Ohki's Tokyo wholesale drug distribution center (Fig. 4.47), and at Sun Bird's franchise logistics center (Fig. 4.48).

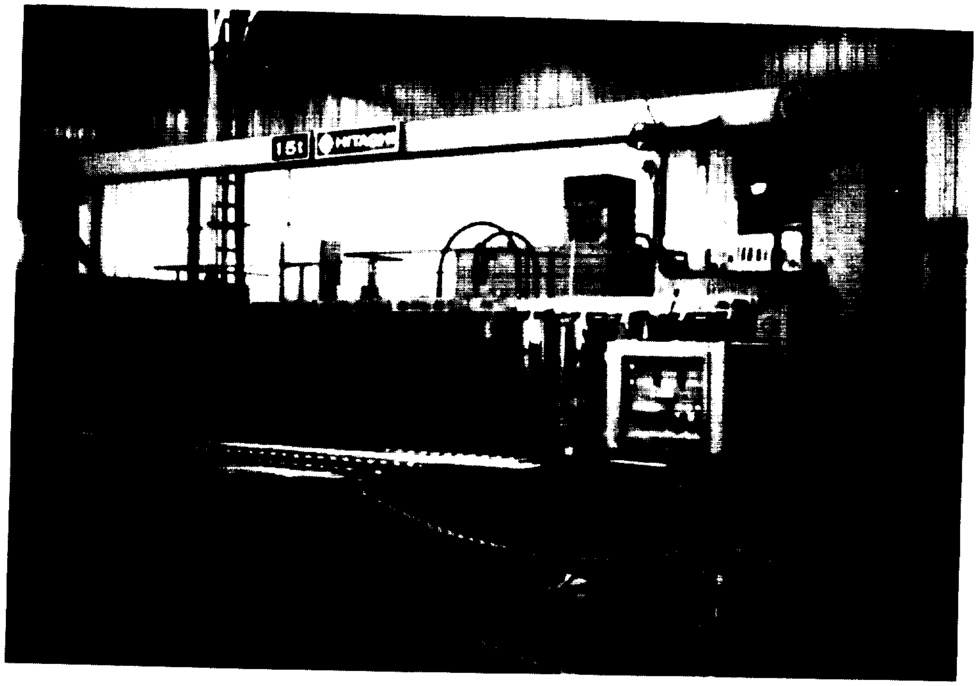

Figure 4.44. Automated Forklifts-1 (Sapporo)

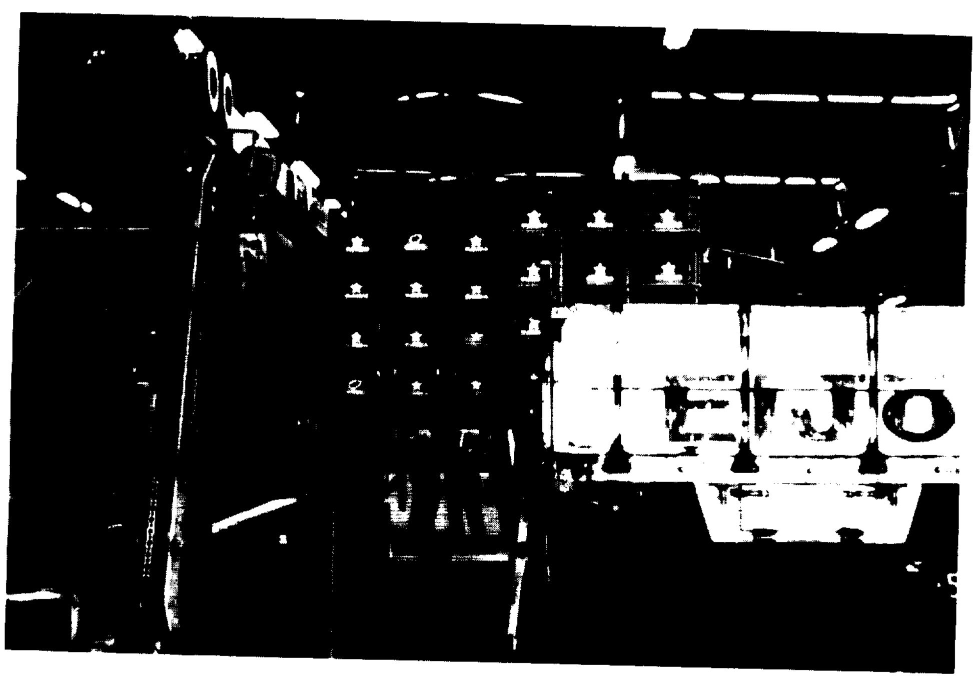

Figure 4.45. Automated Forklifts-2 (Sapporo)

Figure 4.46. Pallet Conveyor (Kao)

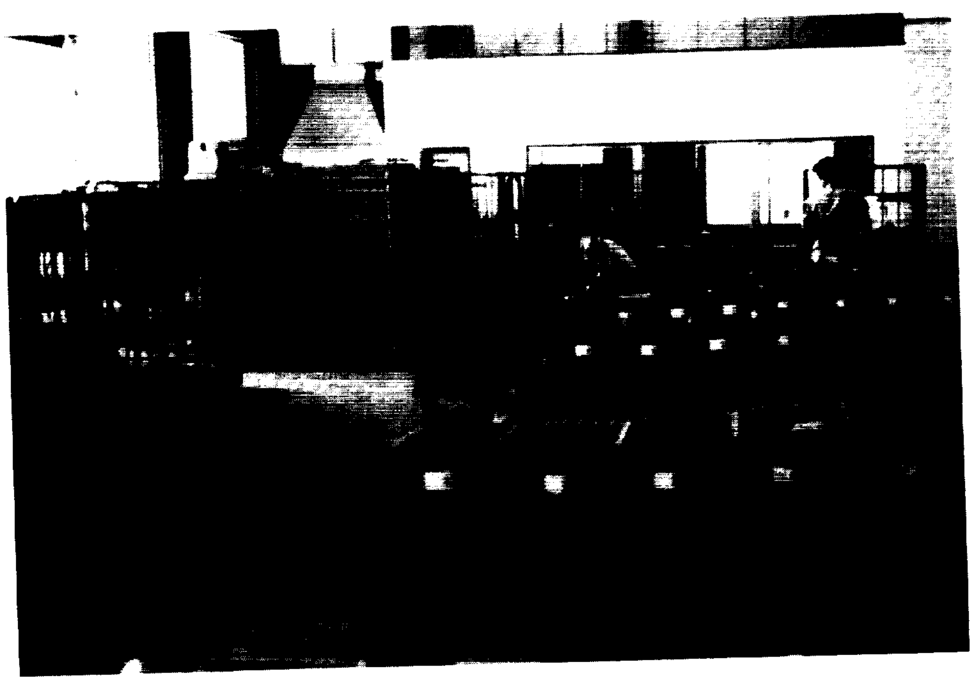

Figure 4.47. Extendable Conveyor-1 (Ohki)

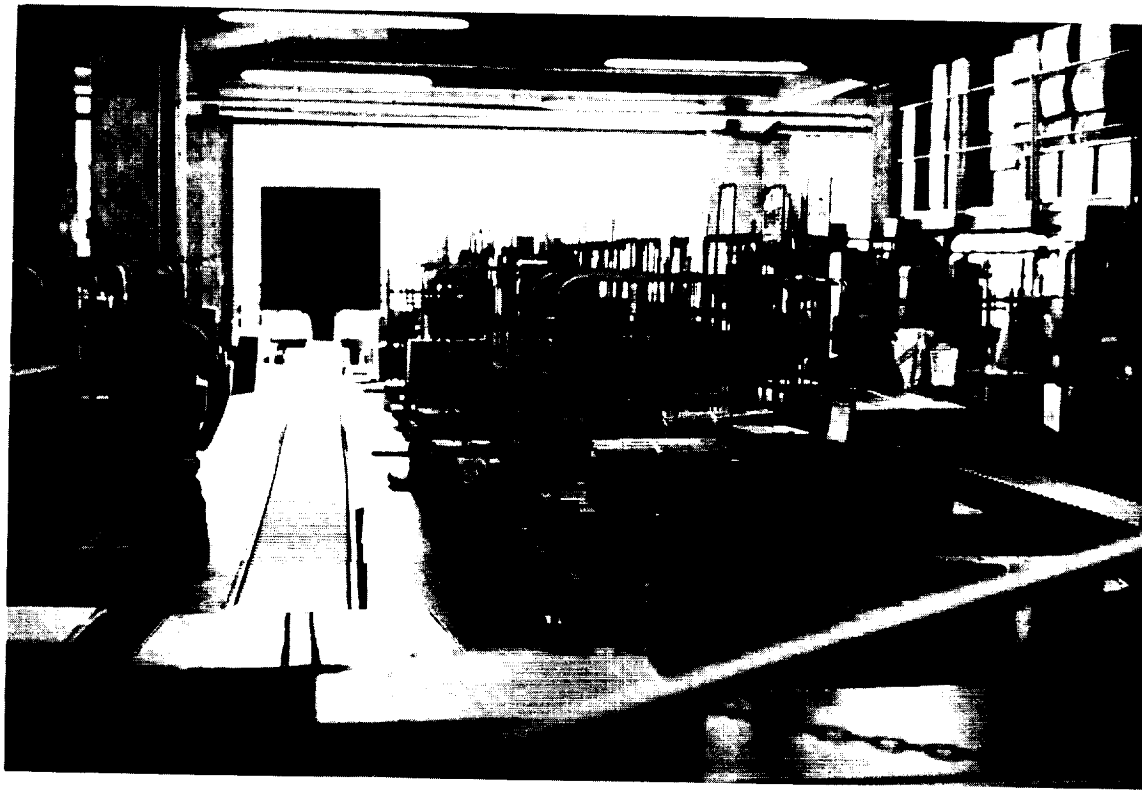

Figure 4.48. Extendable Conveyor-2 (Sun Bird)

Roll Carts. Roll carts are another means for direct loading of totes and/or cases into outbound trailers. An example is at Mutow's Hammamatsu mail order apparel distribution center.

Computer-Aided Dock Management

Smart cards are used to automate and expedite the movement of trailers throughout the site at Sapporo's Chiba distribution center. Once trailer drivers arrive on-site to pick up loads at the DC, they are issued smart cards identifying the drivers, trailer numbers, and the destinations and compositions of the outbound loads. The smart card allows the driver to pass automatically through key check points on the distribution center site. The last verification is at the automatic trailer loading device (Fig. 4.49).

At Suntory's Kisogawa Plant distribution center, automatic voice- and touch-activated terminals at key check points advance drivers past check points and route drivers to the correct docks (Fig. 4.50).

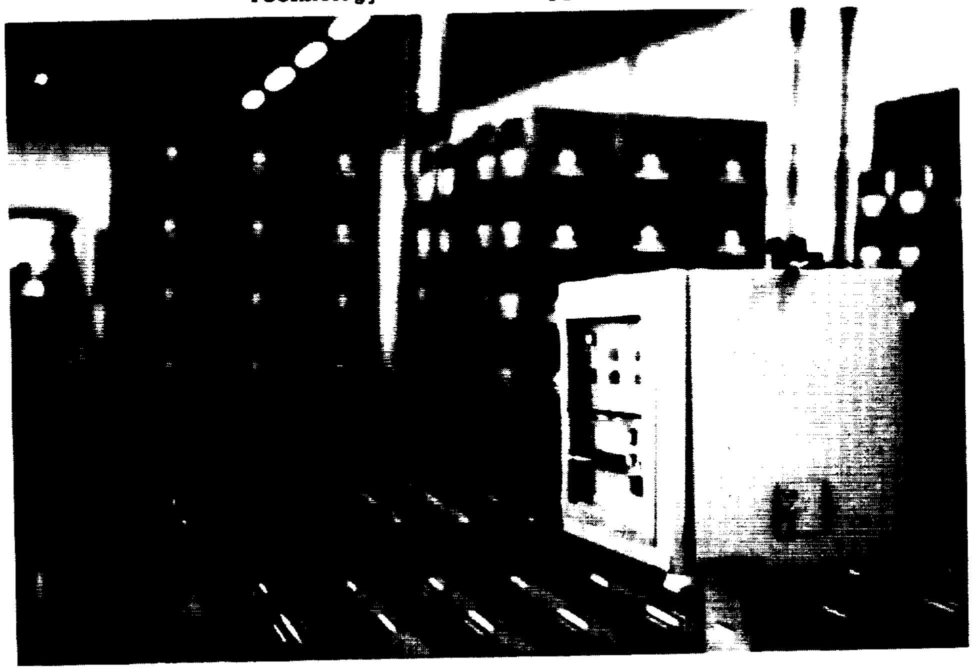

Figure 4.49. Smart Cards-1 (Sapporo)

Figure 4.50 (Left) Smart Cards-2 (Suntory)

At Okamura's office furniture distribution center, an automated dock management system schedules and monitors the flow of inbound and outbound trailers and the use of shipping and receiving docks.

Side-Loading (Gull Wing) Trailers

To further expedite trailer movement and dock turnaround, a majority of the over-the-road trailers are side loading. Examples are shown from Sapporo (Fig. 4.51) and Ohki (Fig. 4.52).

MATERIAL TRANSPORT AND SORTING: FAST, FLEXIBLE, AND AUTOMATED

The design of material transport and sorting systems is governed by high throughput and precision requirements to interface with automated systems throughout a distribution center. Automated guided vehicles, automated electrified monorails, car-on-track conveyors, cross-belt and surfer sorters, and sorting transfer vehicles all meet these requirements.

Automated Guided Vehicles (AGV)

The panel saw traditional wire-guided automated vehicles at Fuji Logitech, Toyota's Kamigo Vanning Center (Fig. 4.43), and at the Tokyo Post Office.

Automated Electrified Monorails (AEM)

Rare in U.S. distribution centers, automated electrified monorails are used in Toyota's Colnet distribution center (Fig. 4.53) and Okamura's Tokyo office furniture distribution center (Fig. 4.54). AEMs provide the same throughput as AGVs, but also free up valuable floor space. Furthermore, AEMs can provide vertical handling capability.

Car-on-Track (COT) Conveyor

SI Handling's CarTrack conveyor system is in place at Sapporo's Chiba brewery, Suntory's Tonegawa beer distribution center (Fig. 4.55), Sony's Tokyo logistics center (Fig. 4.56), and Toyota's Colnet DC (Fig. 4.57). At Sapporo and Toyota the COT conveyors are used for high-velocity AS/RS input/output. At Suntory it is used for load transport away from a case palletizer. At Sony the technology is used for transport and sortation from a vertical conveyor to outbound shipping lanes.

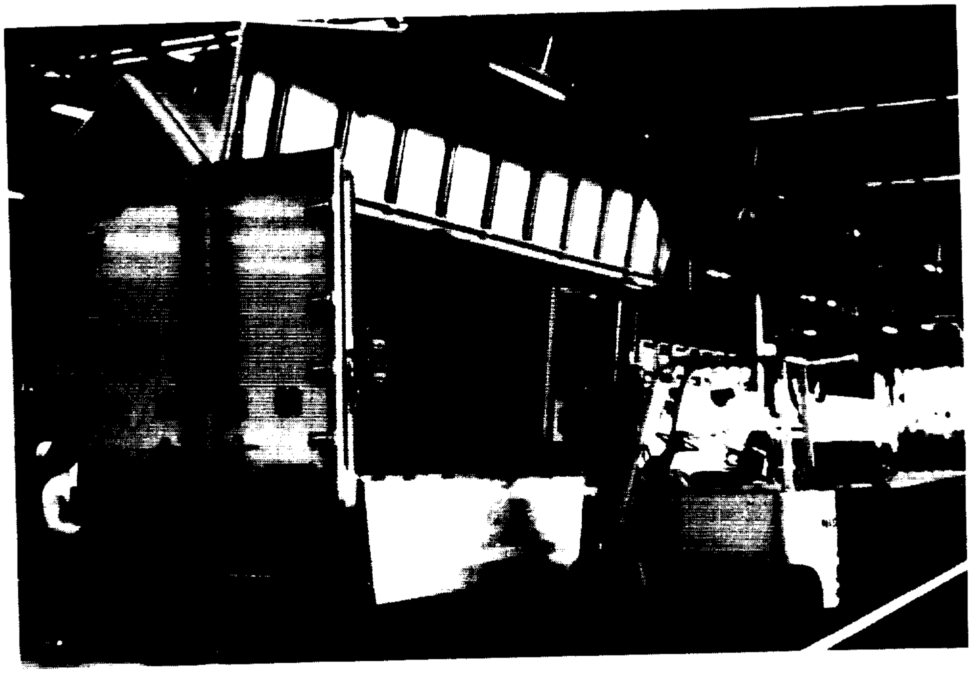

Figure 4.51. Side-Loading Trailers-1 (Sapporo)

Figure 4.52. Side-Loading Trailers-2 (Ohki)

Figure 4.53. Automated Electrified Monorails-1 (Colnet)

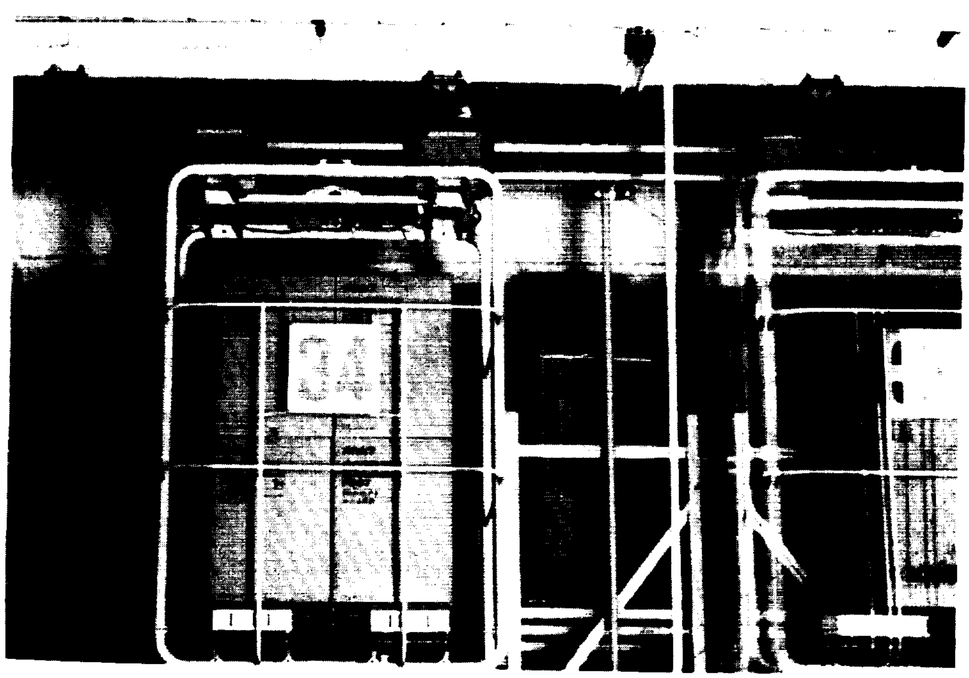

Figure 4.54. Automated Electrified Monorails-2 (Okamura)

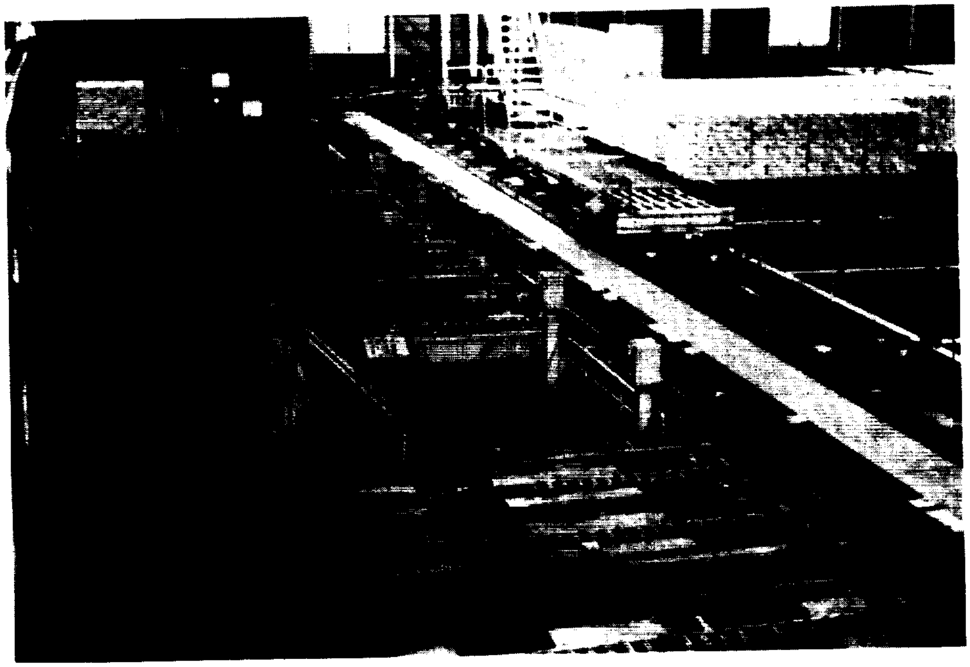

Figure 4.55. Car-on-Track Conveyor-1 (Suntory)

Figure 4.56. Car-on-Track Conveyor-2 (Sony)

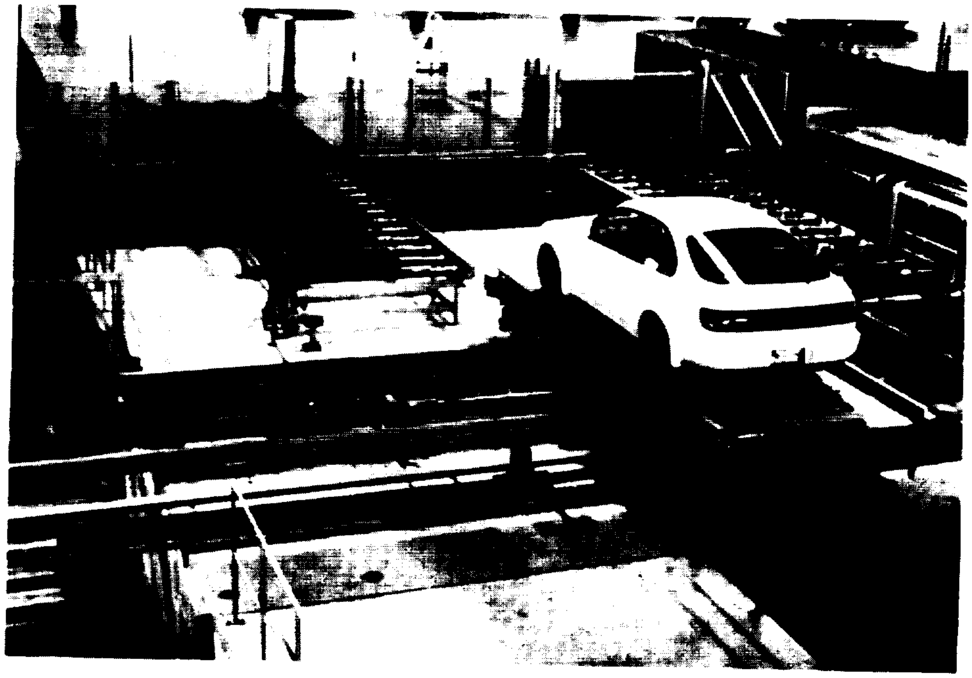

Figure 4.57. Car-on-Track Conveyor-3 (Colnet)

Surfer Sorters

The first surfer (or slat) sorter in use in Japan is at Sun Bird's franchise logistics center (FLC) in Chiba. The sorter offers high velocity sorting and gentle item handling (Fig. 4.58).

Cross Belt Sorters

Cross-belt sorters offer high-speed sortation in limited space due to the speed at which items can be diverted from individual carriers. The panel saw cross-belt sorters at Shiseido's Fukaya cosmetics DC (Fig. 4.32) and Mutow's Hammamatsu mail order DC (Fig. 4.42).

Sorting Transfer Vehicle (STV)

At the ORIX Tokyo distribution center for scientific instruments and computers, a sorting transfer vehicle loop system is used for mini-load AS/RS input/output (Daifuku). The loop STV replaces a traditional conveyorized front-end loop. The acceleration and deceleration, up to and down from 80 meters per minute, provides a precisely controlled, high-performance vehicle.

At Banyu's Tokyo pharmaceutical distribution center, a sorting transfer vehicle manages the flow into a unit load AS/RS automatically.

Figure 4.58. Surfer Sorters (Sun Bird)

Figure 4.59. Handling Units-1 (Kao)

HANDLING UNITS: DURABLE, SPACE-EFFICIENT, AND COLORABLE

A wide variety of unitizing technology is used in Japanese warehouses and distribution centers. At Kao's Iwatsuki City toiletries DC, fish nets are tossed over outbound pallet loads and wrapped with a wide velcro belt to secure the load (Fig. 4.59). At Shiseido and Ohki, collapsible, plastic, returnable totes are used to secure loose items (Fig. 4.60 and 4.61). The colorful totes help create a pleasant working environment. When empty, they occupy minimal space and collapse for transport. At Sapporo's Chiba beer DC and Okamura's Tokyo office furniture DC, plastic pallets are used for their durability and for their positive effect on the work environment.

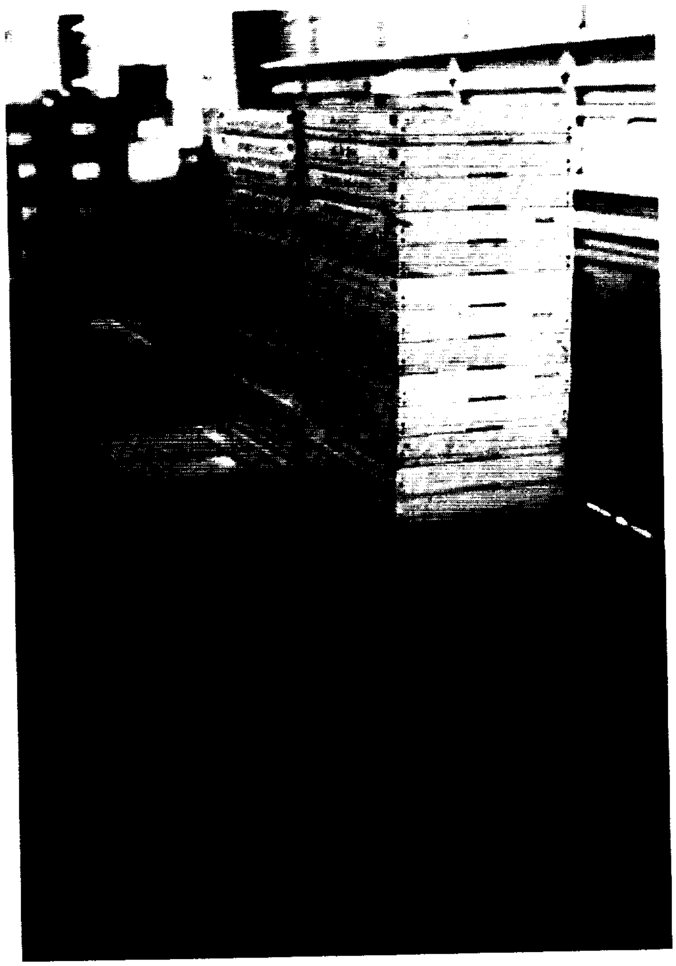

Figure 4.60. (Left) Handling Units-2 (Fukaya)

Figure 4.61. (Below) Handling Units-3 (Ohki)

CHAPTER 5

TECHNOLOGY ASSESSMENT: EQUIPMENT / SYSTEMS DEVELOPMENT

Richard E. Ward
Howard A. Zollinger

AS/RS (AUTOMATED STORAGE/RETRIEVAL SYSTEMS)

Automated storage/retrieval systems technology is used to a greater extent in Japan than anywhere else in the world. This is evident in the variety of applications and in the number of storage/retrieval (S/R) machines produced. For clarity, S/R machines are called stacker cranes outside of the U.S.

In 1990 the AS/RS portion of the total sales in physical distribution systems was $780 million out of the $2.6 billion market. For the purposes of this report, the term "physical distribution" does not include the crane and hoist material handling markets.

The AS/RS technology found in Japan, in general, is at the same level as that in the U.S. and in Europe. In this summary, the variations in technology and the breadth of applications are discussed. More information is provided in the site reports (appendices C-E). The site visits exposed the panel to users and a few manufacturers.

This report has been organized to present the systems, the equipment, the controls and the system computer control. Figures 5.1 and 5.2 illustrate popular front ends to AS/RS installations in Japan.

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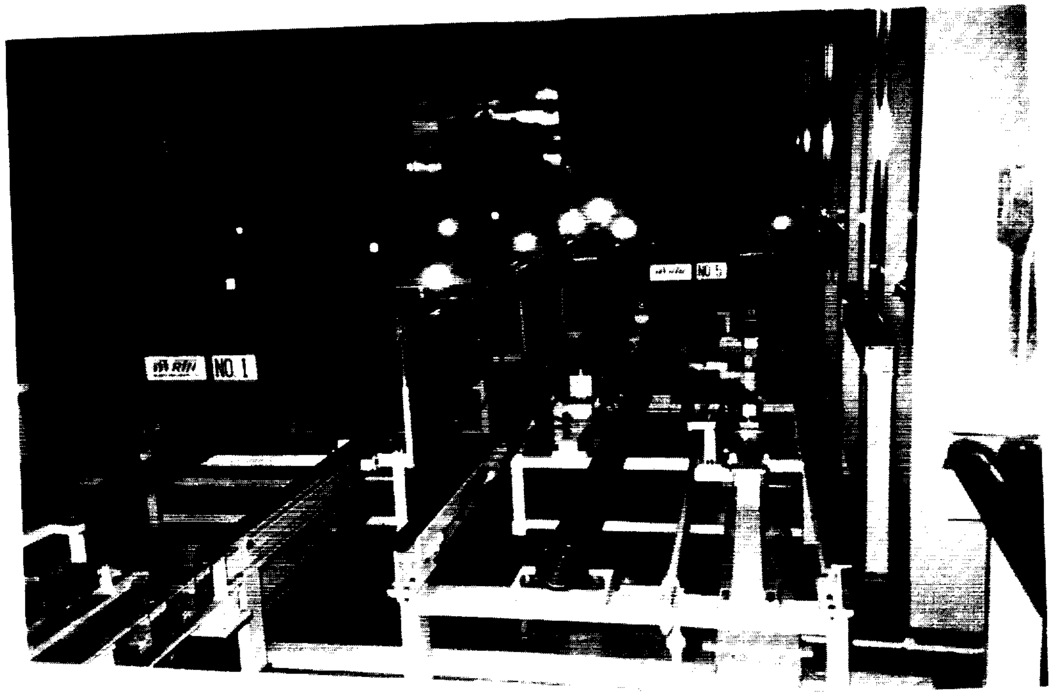


Figure 5.1. Car-on-Track

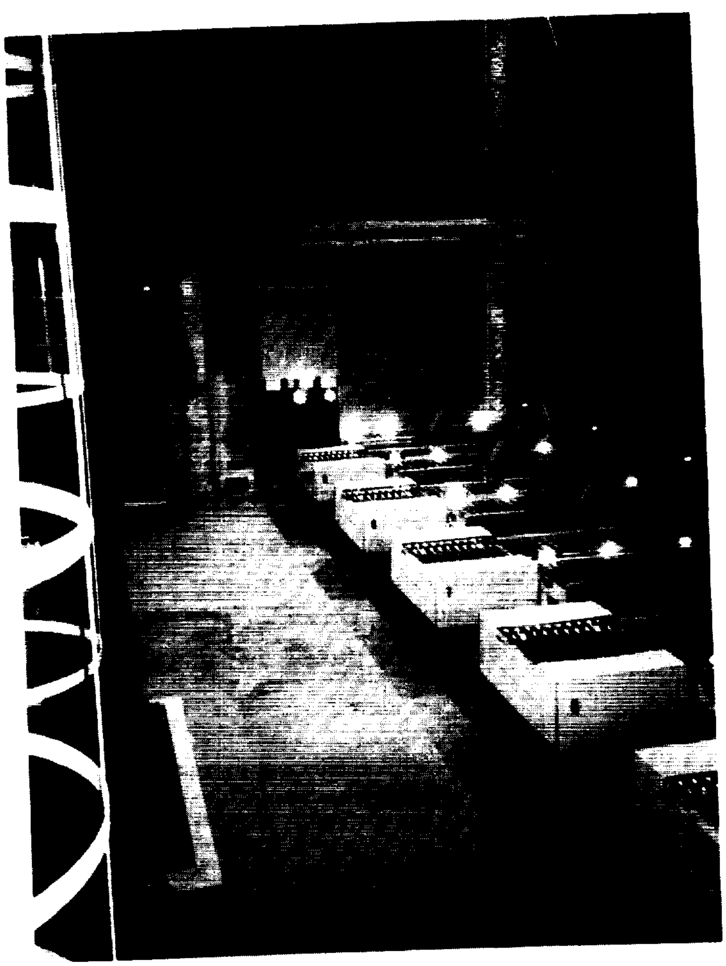


Figure 5.2. (Left) Sorting Transfer Vehicles

Systems

The variety of Japanese applications is more similar to those in Europe than to those in the United States. Part of this is due to the higher cost of land in Europe and its very high cost in Japan. Another part is Japan's drive to be in control and accurate at all times. AS/RS technology is commonplace in almost every manufacturing or distribution industry.

AS/RS is used for reserve storage, buffering work in process, consolidation, and staging prior to shipping. These broad fundamental functions are found in distribution and manufacturing. Another factor is the breadth of industries using this technology. Finally, the dimensions and weight of the load, that is, unit load, mini-load and micro-load, are also factors. The permutations of all four functions give an appreciation of the range of applications.

Equipment

AS/RS equipment focuses on the S/R machines. Also important are the racks, the pick-up-and-deposit (P&D) stations, the input and output equipment, the equipment controls, and the computer system. The controls and computer areas are covered later in this chapter.

In 1990, 2,839 S/R machines were produced in Japan; Daifuku produced 1,511 or 53 percent of these. The total world production was approximately 4,500, with the U.S. producing less than 300 and Europe about 1,500.

One noticeable difference in Japan is the size of the S/R machines. The machines tend to be smaller, that is, shorter than those in the U.S. and Europe. Sixty-four percent are under 33 feet (10 meters), and 86 percent are under 50 feet (15 meters). Some of the minis and micros are 8 to 12 feet high; some unit load machines are 15 to 25 foot high.

In general all of the mini and micro machines have a single mast design, up to 20 feet (6 meters) long. In contrast, almost all unit load machines are double mast designs. The double mast design is considered old technology in both the U.S. and in Europe, except for very heavy (more than 4,000 pounds) and very long loads. Daifuku's newest unit load design is double mast and only 22 feet high.

The newer machines are very clean designs. Most are designed for assembly-line production. The mini and micro machines are extruded aluminum masts for low weight and high performance.

High performance machines are being used and further developed to support the use of many single-aisle WIP systems in manufacturing, and of small consolidation and buffering systems in distribution. Caution is warranted when comparing the throughput of Japanese systems to the throughput of systems in the West. Because of the shorter average length and height of Japanese systems, the performance can be 20 percent to 30 percent higher for mini systems and 30 to 50 percent higher for unit load systems with the same machine performance.

The panel saw fork (shuttle) cycles of five seconds in mini systems and seven seconds in unit load systems. One unit load system shown was capable of 90 dual cycles per hour; the system's capability, after converting for its small size, would be 60 dual cycles per hour. This is 20 to 30 percent faster than the fastest U.S. machines.

With drives on board, the newest micro machines are obtaining performances equal to the fastest U.S. and European machines with the drives off the machine.

There are unique applications in Japan that raise the throughput per aisle. One is a tall mini-load aisle with three short S/R machines stacked one above the other, with the input and output at three different levels. Two high-speed lifts, one for input and one for output, serve the three levels (see Fig. 5.3).

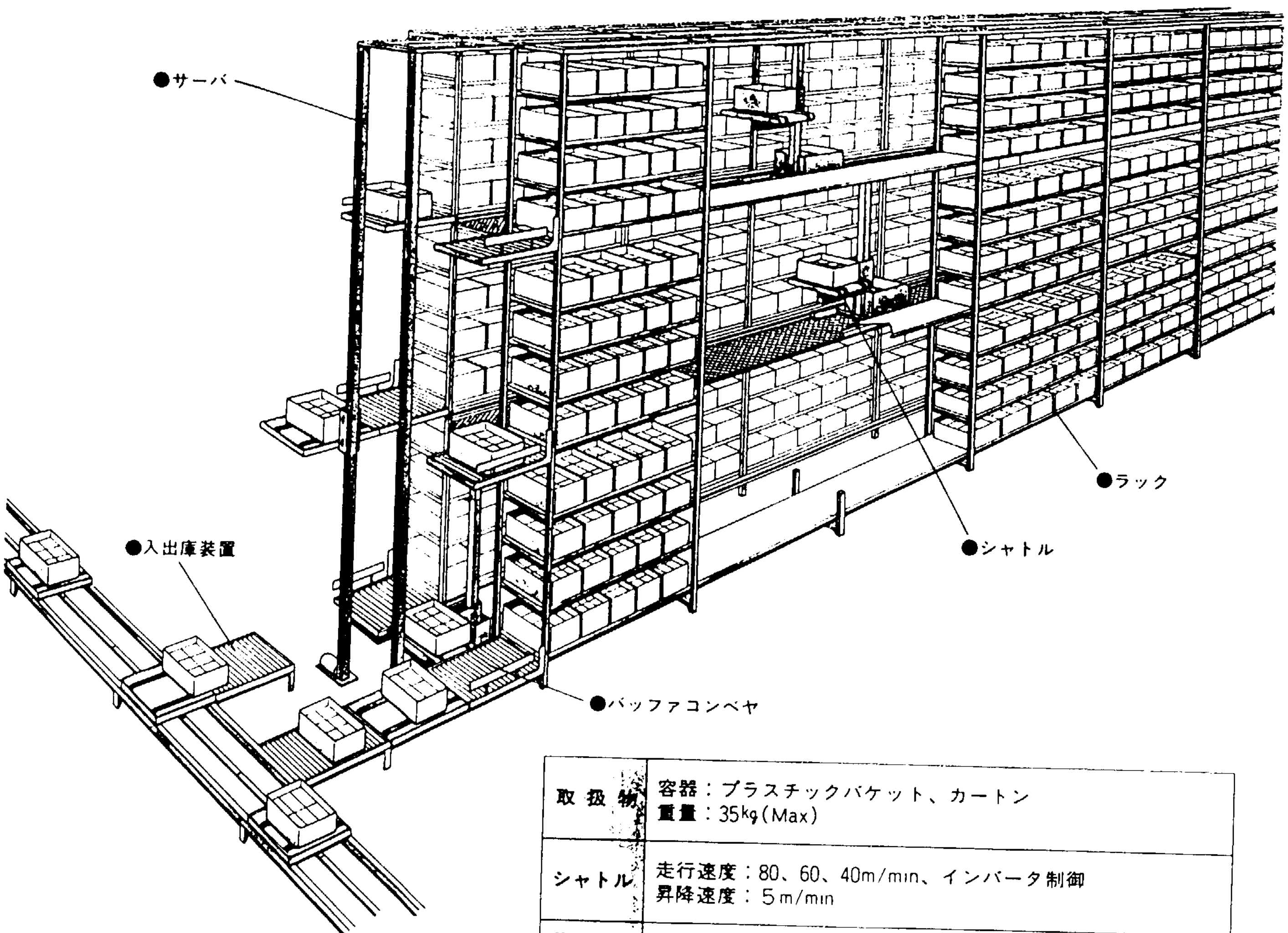
An application also found in Europe is two single-mast machines tied at the top and the bottom to look like a double-mast machine. The benefit of this configuration is that the independent carriages make effective double-store and double-retrieve cycles (see Fig. 5.4).

Japanese racks are little different from those in the West, except for the newest rack design by Daifuku using riveted instead of welded construction. Their front ends often use car-on-track or sorting transfer vehicles (STV) for unit and mini-load systems. These are either spinning tube or shuttle car systems. The P&D construction is normally a conveyor. This is in contrast with completely conveyorized or AGV in the U.S. and in Europe. This is explored further in the conveyor section later in this chapter.

AS/RS Controls

Suppliers have achieved a high degree of standardization with on-board and end-of-aisle controls: As is the case in the rest of the world, Japan suppliers have no industry standard. Some of the newer end-of-aisle controls, in combination with on-board controls, provide maintenance personnel with some friendly "help" features.

Each supplier at the installations we visited was using U.S.-developed photoelectric communication technology with moving S/R machines. Methods employed for finding the correct location and for improving accuracy differed, although there were



取 扱 物	容器：プラスチックバケット、カートン 重量：35kg(Max)
シャトル	走行速度：80、60、40m/min、インバータ制御 昇降速度：5m/min
サ ー バ	昇降速度：30m/min、インバータ制御

Figure 5.3. High Throughput From Three Stacked S/R Machines

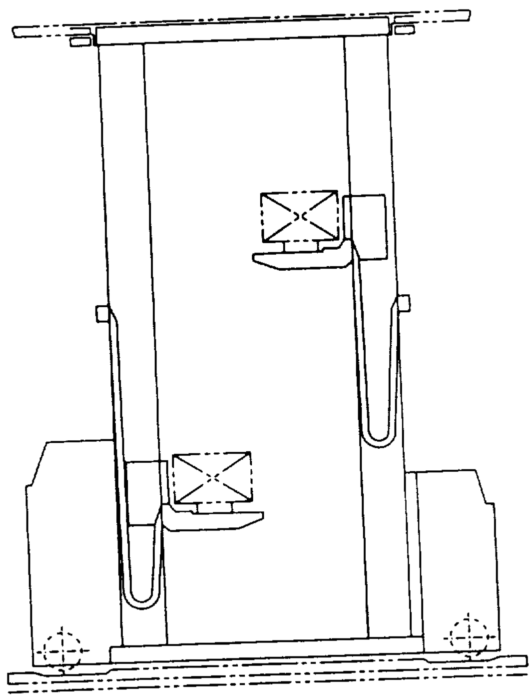


Figure 5.4. Double Store and Retrieve Cycles

no technological improvements over the U.S. and Europe. The controls for the front end transportation system are simple for the spinning tube solution, but require many mechanical and limit switch devices. The shuttle vehicle or shuttle car front end built by Daifuku gives high performance, although not as high as a conveyor, with smart logic on board each vehicle.

AS/RS Computer Controls

Japanese computer controls cover the full range of standard PC systems up to custom mini computer systems. In general there is a more standardized system than in the U.S. for interfacing with the S/R machines' end-of-aisle controls and with centralized material handling computer systems.

Some of the PCs contain the inventory, while in other systems that information is located in the centralized material handling computer system. In the more advanced Japanese systems, there is a connection to the customer's host computer system.

With the centralized material handling computer system, the user is very much involved in establishing how the system will function. Where there is no centralized system, the supplier's standard PC functions are used. It may be of interest to note that one large Japanese system supplier uses a U.S. software house to develop its standard systems.

AS/RS Summary

AS/RS technology is used extensively throughout the U.S. and Europe. The resulting benefits of lower cost and higher reliability are evident. The large number of systems also shortens the execution time and improves start-up predictability.

AGVS (AUTOMATIC GUIDED VEHICLE SYSTEMS)

Automatic guided vehicle systems have proven to be extremely popular (and apparently successful) in Japan as a method of transporting unit loads in a wide variety of applications. The statistics presented in Chapter 2 of this report are evidence of the rapid growth in Japanese AGVS installations since 1985, and of how much more popular AGVSs are in Japan than in the United States.

Despite the overwhelming number of installations and the number of vehicles in operation in Japan, both the variety of applications and the functionality of Japanese vehicles compare favorably with applications and vehicles found in the U.S. This opinion is based on observations made at major Japanese material handling trade shows as early as 1989 as well as during the panel's site visits in April 1992. The panel found no new evidence during these latter visits suggesting any new or unique technological developments that place Japanese suppliers ahead of suppliers in the United States.

However, industry watchers in the U.S. should not interpret this as a cause for relief. There is indeed a real need for continued vigilance in studying the AGVS industry and other automation technologies in Japan. That need is based on concern over what effect such a high demand (i.e., end-user willingness to apply automation technologies) is having or will have on current and future research and development. R&D is undoubtedly fueled by continued market support for new and better products. In addition, the high volumes certainly can lead, and in at least one case already have led, to developments aimed as much at lowering manufacturing costs (i.e., design for producibility) as at increased vehicle/system functionality or flexibility.

Guidance and Control

The panel examined the area of vehicle guidance and control more closely than any other specific technology comparison. Virtually every method of guidance and control present in the U.S. is present and under development in Japan. Examples include buried wire guidance, magnetic strips, optical guide paths, laser (target) navigation, inertial (off wire) guidance (including navigation between discrete transponders or buried magnetic markers), and a form of vision-based guidance employing overhead mounted charge-coupled device (CCD) cameras. On the communications side, both radio frequency (RF) and infrared (IR) communications are widely used. The latter is primarily used for vehicle communication at or near docking (P&D) stations. Both of these communication methods have been in use in the U.S. for some time.

The Swiss-based Digitron license is one example of a well-known control license in Japan. Also, the Swedish firm NDC, well known for its control licenses in the U.S., has a presence in Japan.

Although there are several AGVS suppliers in Japan, many of which are also well known fork truck manufacturers, the panel only met with representatives of three, one of whom spoke openly about his company's AGVS developments. While the company uses a variety of control and navigation methods, its primary method is to follow a thin, plastic-encased magnetic strip epoxied to the floor. Recent advances include development of an ultra-thin (and beveled) plastic-encased magnetic strip that is less susceptible to damage by other traffic such as fork trucks. Another development believed to be still underway is the use of very thin, floor-mounted ceramic transponders for communication/navigation purposes as opposed to the larger, magnetic plugs that must be sunk into the floor.

A Case Study

A very unique application at Fuji Logitech is worthy of note for two reasons. The application features an AGVS equipped with a carton clamping attachment that block stacks white goods (appliances) in a public warehouse. Neither a vehicle with a carton clamp or block stacking is unique in and of itself. What distinguishes the application is the control system and method of operation.

In this case the end user designed and took total responsibility for the development of the control system and its integration into the local host computer and the inventory management system. The vehicle and the basic control/navigation requirements were specified by the user; the vehicles were procured from the most responsive supplier; and then the user began integration. The panel is unaware of any instance in the U.S. where an end user has taken responsibility for an installation that even came close to this example. Nevertheless, this example does point to a way of doing business that could have great potential in the U.S.

The other distinguishing feature of this case is the fact that the vehicles operate in a totally unmanned section of the warehouse. When the work force goes home at night (5:30 p.m. to 6:30 p.m.), the AGVs operate on their own, storing and retrieving loads throughout the night. They are referred to affectionately as the "night shift."

The end user reports that down time and maintenance (other than routine preventive maintenance) has never been a problem at this installation.

Additional Observations

The trends referred to earlier were based on aggregate statistics presented in Chapter 2. Additional insight into applications can be gained from studying Figures 5.5, 5.6 and 5.7. The first two demonstrate trends by comparing two contiguous periods, that is, 1984 to 1986 versus 1987 to 1989. The first graph shows an increase in the percentage of applications where unit load (e.g., roller-deck) vehicles are automatically loaded and unloaded at P&D stations. It also shows an increase in the number of tugger applications and a slight increase in the number of forklift-type AGVs.

The second graph shows more than a 100 percent increase in the applications where vehicles are handling loads of less than 100 kgs total weight. In fact the only other weight category with an increase, albeit only a few percentage points, is in the range of 500 kgs to 1,000 kgs.

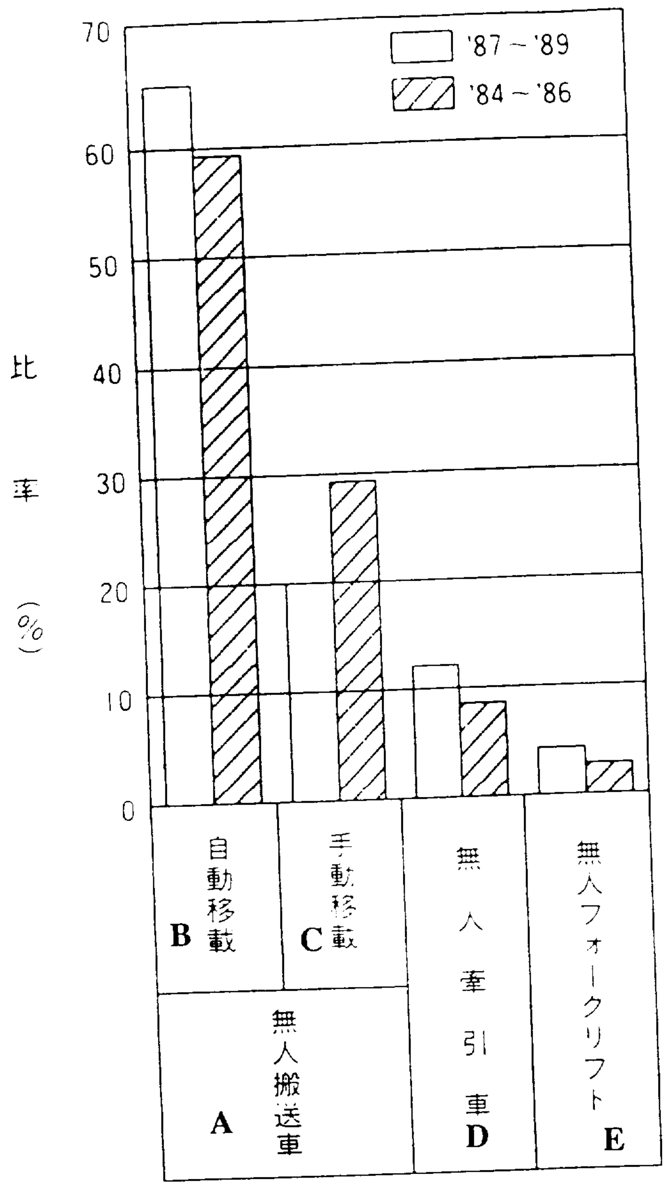
The last figure (Fig. 5.7) contains a breakdown of AGVS applications by user category. The largest single category of users is the electronic equipment industry (37 percent), followed by the automotive industry (19 percent).

CONVEYOR

Much of the conveyor product line in Japan was developed based on license agreements with U.S. companies. Many of these ties are still in place, although they are not as important as they once were.

In 1990 the conveyor portion of the total sales in physical distribution systems was $245 million out of the $2.6 billion market (once again, physical distribution does not include the crane and hoist material handling markets).

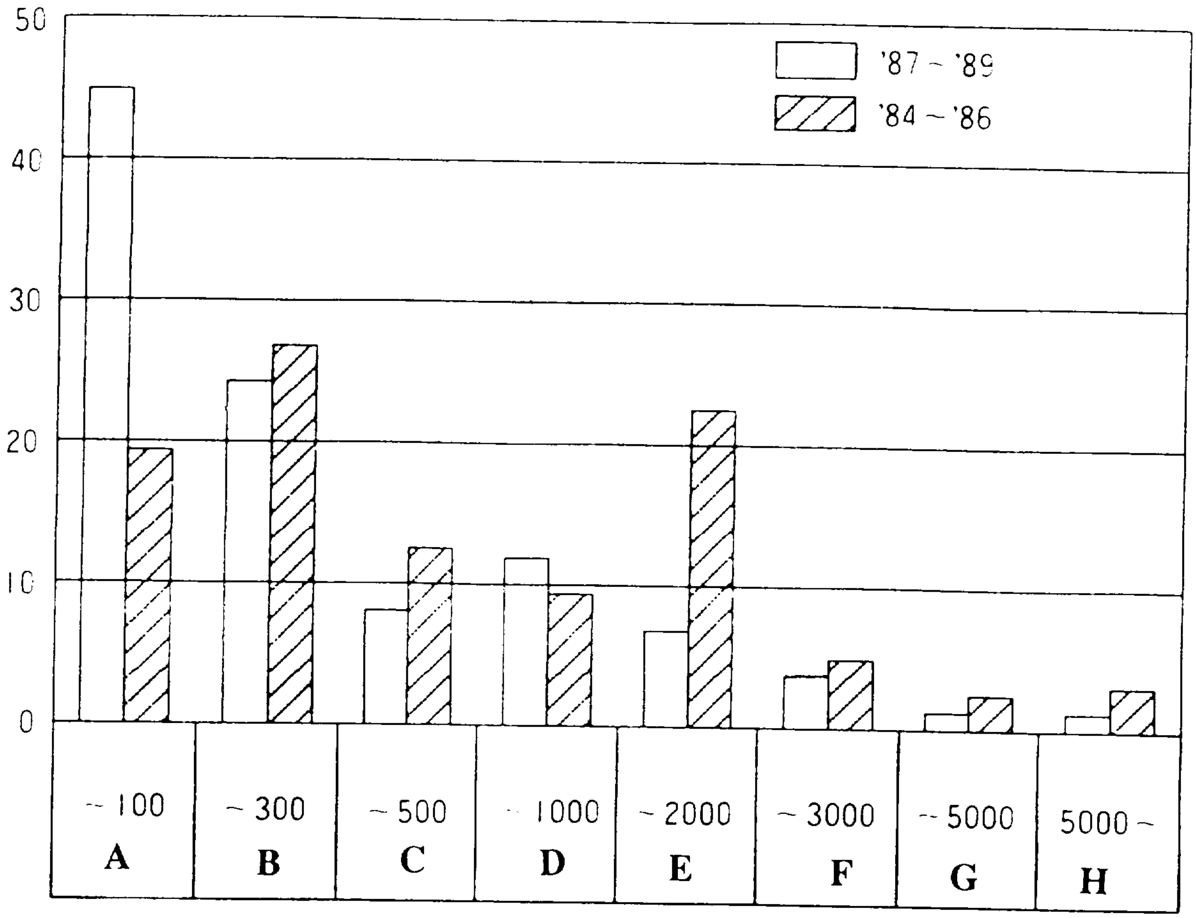
One of the earliest post-World War II Japanese developments in material handling came when Toyo Kanetsu K.K. negotiated and established a license with Rapistan for package conveyor technology, including the famous APC accumulation conveyor. Then came Daifuku, which established a license with the J. B. Webb Company for chain conveyors, both straight power and power and free types.



*Key

A = Unit Load Vehicles (ULV)
B = ULV with fully automatic load/unload
C = ULV with semi-automatic or manual load/unload
D = Tuggers
E = Fork lift

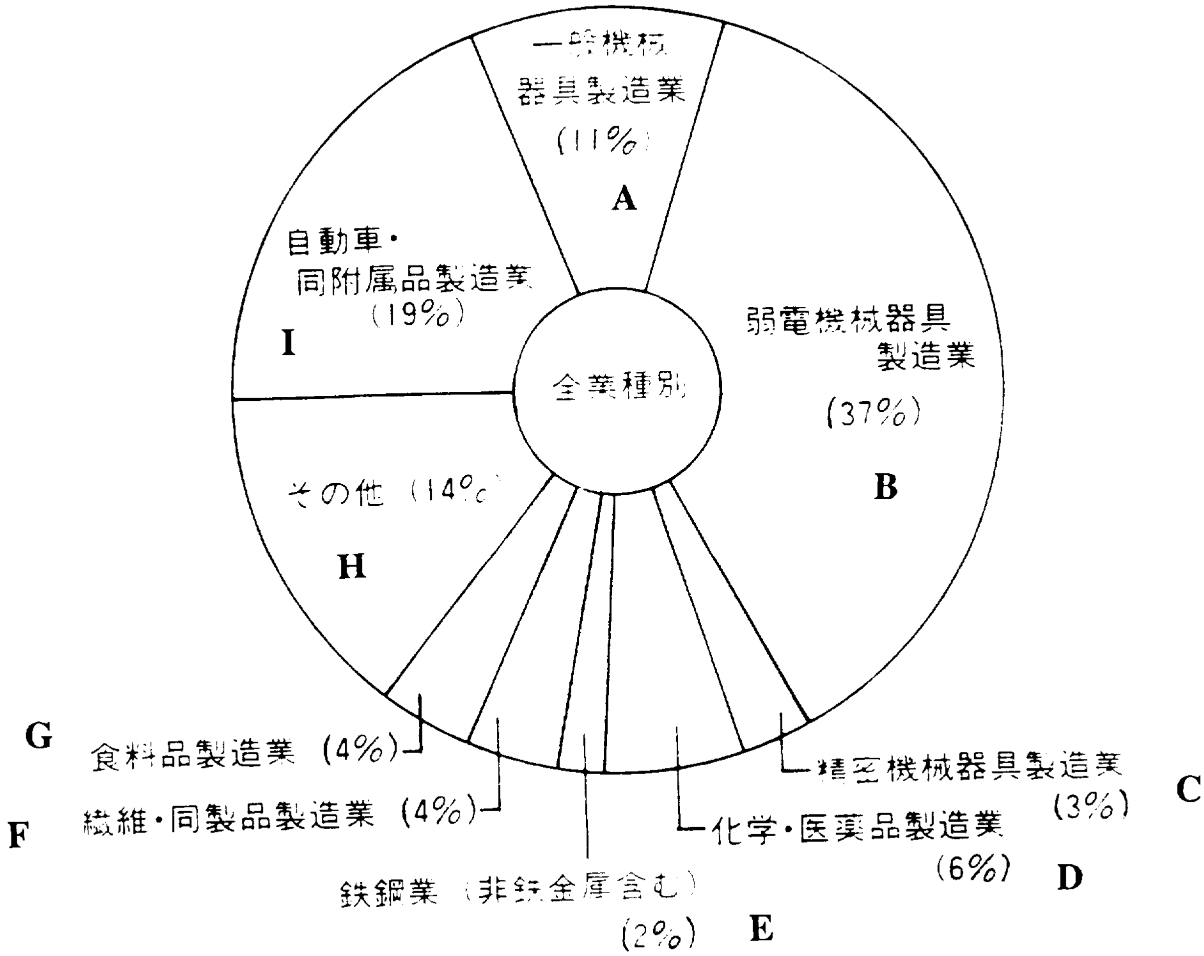
Figure 5.5. Percentage of All AGVS Applications Versus Vehicle Type



Key

A = Less than or equal to 100 kg
B = Greater than 100, less than or equal to 300 kg
C = Greater than 300, less than or equal to 500 kg
D = Greater than 500, less than or equal to 1000 kg
E = Greater than 1000, less than or equal to 2000 kg
F = Greater than 2000, less than or equal to 3000 kg
G = Greater than 3000, less than or equal to 5000 kg
H = Greater than 5000 kg

Figure 5.6. Percentage of All AGVS Applications Versus Payload Categories



***Key**

A = **General Machinery**
B = **Electrical/Electronic Equipment**
C = **Precision Machinery**
D = **Chemical and Medical**
E = **Steel (Basic Metal)**
F = **Textile**
G = **Food**
H = **Other**
I = **Automotive**

Figure 5.7. Percentage of All AGVS Applications Versus End User Industry Categories

Now Japanese companies have developed standards to meet the Japanese desire for aesthetics, low noise, and high reliability. In a few areas, the Japanese have a lead over the U.S., but not over Europe.

The existing license arrangements are still in place for palletizers and high speed sortation. Most of the conventional conveyor product agreements are gone.

High Speed Sortation

There are several licenses for high-speed sortation. One Japanese company has developed cross belt sorter technology, and a few others have licensed similar technology from U.S. companies.

The greatest amount of licensing has been for the new high-speed shoe sorter or "positive sorter" from four or five U.S. companies. About 10 years ago, pop-up wheel or pop-up roller technology was licensed by a few U.S. companies and inventors. Some of the Japanese companies have improved on what they received.

Japan's conveyor leaders have realized their dependence on U.S. technology in this field. At least two have been making improvements on what they license.

Aesthetically Pleasing and Low Noise Conveyors

The Japanese and European cultures place value on aesthetics and low noise. This has lead the suppliers to design roller and chain conveyors with clean lines and the flexibility to install, move and adjust sensors.

The Japanese have developed aluminum extruded side channels with many slots for sensors and their mountings. Although initially this was more expensive, it probably is not now. Some Europeans have been manufacturing this equipment longer than the Japanese. It is rare to see it in the U.S. because of the cost.

Special designs are made in this same conveyor to keep the noise low. Japanese industry insists on noise below 75 dB, where in the U.S. it is 85 dB. Often Japan and Europe require below 70 dB, but the United States will permit 88 dB.

Accumulation

At several locations the JTEC panel saw photoelectric sensors instead of mechanical sensors for accumulation conveyors. The actuators were air operated with electric sensing that worked well to remove some of the noise. One supplier uses individual actuators on each roller.

All Other

All other conveyor systems, including chain products, were mechanically comparable to U.S. systems.

Conveyor Controls

There has been a trend towards using modular controls for conveyor systems. At one Japanese site, the panel saw a single controller per two or three pieces of conveyor. This control was tied to a proprietary local area network (LAN) to connect all areas of the conveyor system. This significantly reduces the cost of field wiring.

Conveyor Summary

The majority of Japanese conveyor technology is the same as in the U.S. In the areas of aesthetics and noise reduction, the Japanese are ahead. In the high-speed sortation area, the U.S. is ahead. The challenge will come if technology transfer leads to two-way licensing arrangements in the 1990s.

CAROUSEL (ROTARY RACK)

There is substantial interest in carousels (or rotary racks) in Japan. Technical press and conference programs include many articles written on carousel technology, including application guidelines, calculation of throughput, PC controls for efficiency and inventory control (multilevel versus conventional), and fuzzy logic.

There were only two applications that had an effect on 1990 sales. In 1990 the carousel portion of the total sales in physical distribution systems was $30 million of the $2.6 billion market (not including cranes and hoists). The $30 million figure may seem low, but the average carousel manual unit costs between $50,000 and 75,000; automatic units range in price from $70,000 to $125,000 each.

During the Banyu Pharmaceutical site visit, the panel saw a very interesting application of two multilevel carousels: they were used for order consolidation ahead of shipping. The two units automatically loaded and unloaded carton products. This use can be applied to other situations.

At another site visited by the panel, a multilevel "ladder loading" device supplied by Okamura was operating. This was used with an independently rotating, multilevel carousel that provided loading or unloading at all levels at one time. The ladder was loaded while level, and lowered to unload items at each level. Each rotary rack level was positioned with an empty bin to match the loading ladder. To unload, the rotary rack levels positioned their bins opposite the ladder position for that level and unloaded all of the bins simultaneously. The ladder raised to the top position and the articles marched off like little soldiers.

Controls have become simpler and simpler. They also can be smarter if designed to work on a few products.

Carousels Summary

The carousel market is probably strongest in the areas of manufacturing and small parts. As more knowledge is gained about what constitutes good application, more will be applied. The lower cost mini and micro storage systems in Japan have a bearing on the need for carousels.

CONTROLS

Material handling control technology, including computer control, has made excellent progress in Japan as well as in the rest of the world. With more use of material handling in Japan, it would be easy to say that Japanese controls are more advanced. However, this is not true; the technology is on a par with that in the U.S. and in Europe.

According to market data, the computer portion in the physical distribution system was $150 million in 1990. There are no statistics for the controls value included in these systems.

For those seeking a more detailed discussion of controls, previous sections in this chapter have dealt more extensively with AS/RS controls and AS/RS computer controls.

Typical Advanced Distribution Center Controls Architecture

The panel inquired about computer controls at most sites to obtain an overview of their degree of sophistication and reliance on the system. At one site, the scheme shown in Figure 5.8 is actually in use; it is representative of other advanced systems.

The architecture falls into the classic five-level chart used in many textbooks on material handling: level 1, power controls; level 2, function controller; level 3, system directors or area computers; level 4, facility director or material handling computer; and level 5, user's data processing system or multilevel network.

Figure 5.8 shows the typical system from peripherals and operator's input or output devices up through levels 3, 4 and 5. It is common for the larger material handling systems suppliers to do the software for the level 4 material handling computer to the customer's operational requirements. A few customers do this themselves.

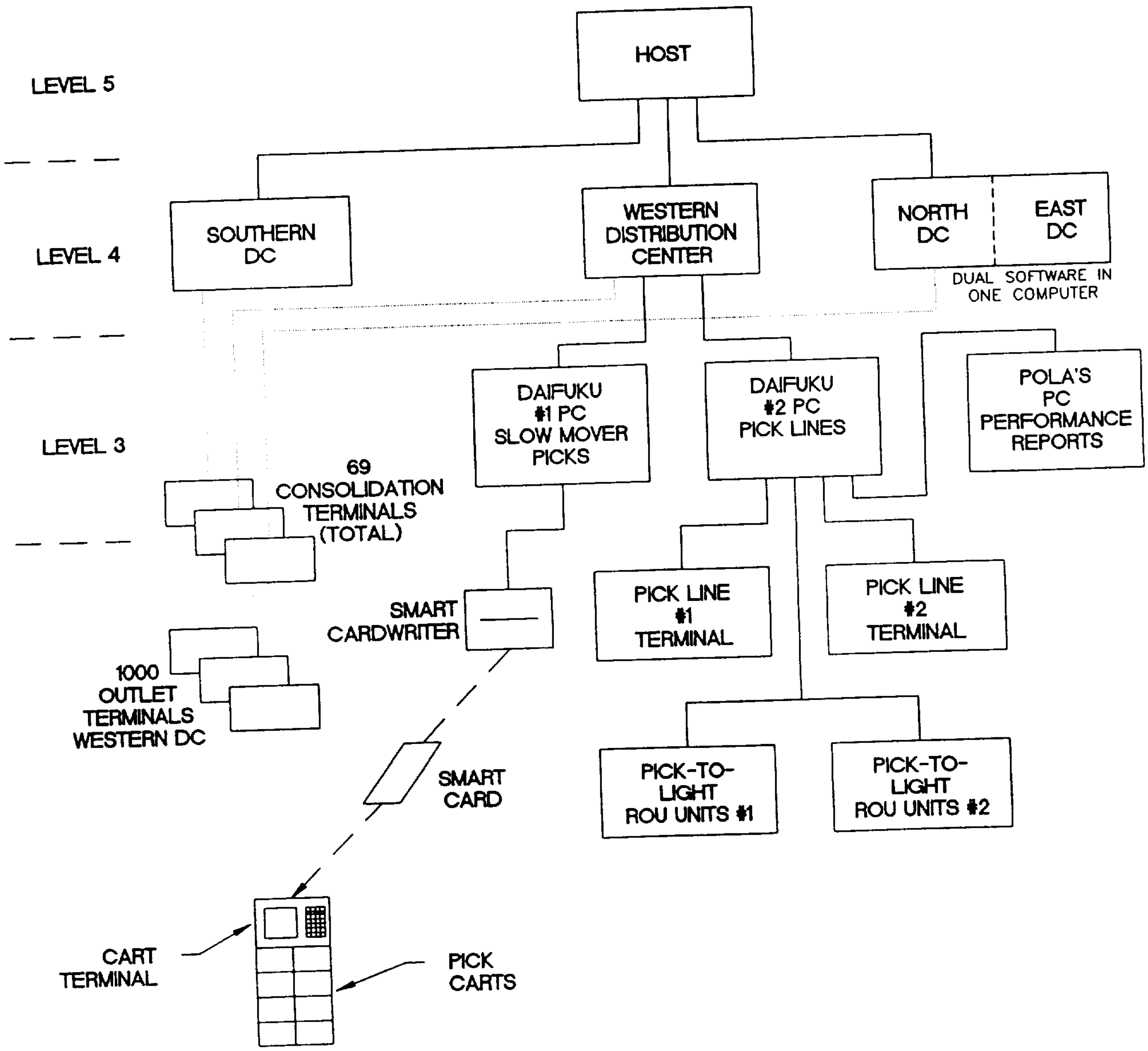


Figure 5.8. Distribution Center Computer System Architecture

Picking Systems -- Pick-to-Light

There are several picking systems working in Japan. Pick-to-light has been chosen as one to discuss because of the number of site visits where it was present. Modern pick-to-light technology was developed in the U.S. and licensed to Japan 15 to 20 years ago. The Japanese have applied the technology to many more installations than it has been applied to in the United States.

Pick-to-light systems rely on a small computer (the PC, today) to transmit commands to digital readouts at each bin or flow rack. The commands indicate the quantity of individual pieces or cartons per item (SKU) to be picked for the order passing by on a conveyor. There are as many arrangements as suppliers or customer applications. Everyone starts with standard read-out-units (ROU), wiring techniques, and software, customizing them to provide a system.

Picking Carts

Picking cart systems are starting to become smarter and easier to use. The easier to use, the higher the productivity.

There are a number of fully-automatic and semi-automatic systems installed. With Japan's shortage of workers over the next five to fifteen years, there will be many more. The controls will be key to their success.

Controls Summary

Japanese controls technology is on a par with that in the U.S. and Europe. The newest AS/RS controls have some user-friendly maintenance "help" built in. S/R machines in Japan are using a U.S. development for in-the-aisle communication.

Computer controls typically involve a full range of PCs connected to the centralized material handling computer or to the customer's host. Some PC systems have inventory data; others maintain inventory in the central material handling computer.

Conveyor controls are becoming more modular and are typically tied together by LAN to reduce wiring costs and engineering. The typical advanced distribution center controls architecture in Japan is the same as that found in the U.S. The typical five-level chart applies.

Pick-to-light systems are used extensively and accuracy is very high. Picking carts are not on-line as in Europe and in the U.S., but are effective nevertheless.

CHAPTER 6

TECHNOLOGY ASSESSMENT: RESEARCH

Richard E. Ward

INTRODUCTION

The subject of equipment/system developments was covered in the preceding chapter; therefore comments in this section will be limited as much as possible to basic research and development. And, since very little direct evidence was found, many of the comments will be conjectures based on what could be pieced together from personal knowledge, the site visits, a survey of published literature, and interviews with various individuals.

Literature Review

Two separate computer literature searches were conducted prior to making the site visits. The first, made of the Japan Information Center of Science and Technology (JICST-E) data base, produced a scanty return of only forty-eight items. Even though "material handling" was used as one of the primary descriptors, none of the returns yielded subjects that could be described as either research or development.

The second search was of Dialog's *Japan Technology* database. Although the number of hits was significantly larger, again there was very little evidence of what might be called current basic research. Indeed, most of the articles, based on a reading of fairly lengthy English language abstracts, were descriptive of products and their applications. Table 6.1 describes the principal equipment categories that have been written about.

Table 6.1
Frequency Tabulation and Characterization of Articles Obtained in Literature Search

Principal Focus

Material Flow Cntrl/ Inventory/Logistics	39	(16.%)
Manipulator/Robots	33	(14%)
AGVS	29	(12.3%)
Controls	17	(7.2%)
Cranes	12	(5.1%)
Palletizing	10	(4.2%)
Bar Coding/Auto ID	9	(3.8%)
Parts Feeder	9	(3.8%)
Conveyors	8	(3.4%)
Mechanical Actuators	8	(3.4%)
Bulk Handling	8	(3.4%)
Production Planning	7	(2.9%)
Fork Lifts	7	(2.9%)
Warehousing	7	(2.9%)
FMS	6	(2.5%)
Cargo Handling	5	(2.1%)
Algorithms	4	(1.7%)
Elevators	4	(1.7%)
Assembly	4	(1.7%)
CIM	4	(1.7%)
Process Handling	3	(1.3%)
Truck Loaders	3	(1.3%)
Vacuum Manipulators	2	(.85%)
Maintenance	2	(.85%)
Sortation Conveyors	2	(.85%)
Artificial Intelligence	2	(.85%)
Human Factors	1	(.42%)
Air Pallets	1	(.42%)
Racks	1	(.42%)
Testing	1	(.42%)
Weighing	1	(.42%)
Pneumatic Conveying	1	(.42%)
AS/RS	1	(.42%)
Loading	1	(.42%)
Total	236	

Type of Article

General Review	189	(44.6%)
Application Description	119	(28.1%)
Patent/Product Description	50	(11.8%)
Management Issues	32	(7.5%)
Market Statistics	15	(3.5%)
Theory	9	(2.1%)
Experimental	8	(1.9%)
Review	2	(.47%)
Total	424	

As shown in the table, the number of articles totaled 424, but the frequency distribution by type/focus is based on a sample of only 236. The remaining articles (424-236) were either so general that they were difficult to categorize, or the topic was not at all related to the subject of material handling.

Most of the articles appeared in either company publications or trade magazines. For example, all of the material flow/inventory/logistics articles were found in these sources, and were described as either providing a general review or addressing management issues. In some respects this rather unrevealing result from the literature search is not surprising in light of the language difference and the limited ability of an English-language abstracting service to cover other than very general literature sources.

THE RESEARCH INFRASTRUCTURE

From what could be learned, virtually all product development and basic research related to material handling technology is conducted solely by equipment suppliers in their labs. There does not appear to be any consortium-related R&D other than on issues that might be considered very general and that are at a level where overall needs, national policies and priorities are discussed.

There is virtually no direct company sponsorship of research at the university level that could be tied specifically to material handling. Certainly there is no product development-related research being done at universities that could be identified. While there undoubtedly is basic research conducted at universities, its relationship to commercial material handling needs is probably more coincidental than deliberate. The one possible exception to this opinion, where the connection to material handling is better defined, will be discussed later.

Experience in the U.S. regarding corporate sponsorship of university-based material handling research is different. Contrary to Japan's experience, there are many examples in the U.S. of direct corporate sponsorship and funding. The most notable example is the Material Handling Research Center (MHRC) at the Georgia Institute of Technology. The MHRC program began in 1982, and has twenty-five to thirty different corporate sponsors annually. Many of the corporations have been sponsors since the MHRC's beginning. Examples include:

AT&T	Dupont
Coca Cola	Eastman Kodak
Xerox	Litton IAS
GM	Stanley-Vidmar

Other examples of U.S. universities that have received corporate support for basic research related to material handling include University of Arkansas, Pennsylvania State University, University of Massachusetts (at Amherst), Purdue University and Stanford University.

In Japan there is no government or quasi-government/agency sponsorship of university research related to material handling. This too contrasts sharply with the proactive role of the National Science Foundation (NSF) in fostering university research, especially university-industry cooperative research. For example, an NSF initiative in 1991 directly targeted "Intelligent Material Handling" in its solicitation of proposals. Another sharp contrast is how material handling research is fostered in the U.S. at the trade association level. For example, in 1990, the Material Handling Industry of America (MHIA) through its College Industry Council for Material Handling Education (CIC-MHE) sponsored a National Material Handling Research Colloquium. NSF and the following companies cosponsored the event:

Accu-Sort Systems
Allen-Bradley Company
Blue Giant Equipment
Cahners Publishing
Litton IAS
Mannesmann-Demag
Penco Products
Rapistan
Republic Storage Systems
Stanley-Vidmar
Unarco Material Handling

This colloquium influenced the NSF Intelligent Material Handling Initiative. In 1992 the colloquium was again sponsored by MHIA and CIC-MHE, and cosponsored by the NSF and the U.S. material handling companies named above, along with:

Alvey
Harnischfeger Engineers
Liftomatic
Penton Publishing
Prime Mover
J.B. Webb

GENERAL RESEARCH DIRECTIONS IN JAPAN

There are consortia-related activities underway in Japan that are exploring top level issues in which material handling has a role. The two principal examples are the IMS initiative and one called Manufacturing 21.

IMS

IMS is short for "Intelligent Manufacturing Systems," and is a quasi-government, industry and university initiative begun in 1990. This was an outgrowth of an earlier Factory Automation (FA) working group within the Ministry of International Trade and Industry.

This working group consisted of six MITI/AIST laboratory personnel and representatives from the following companies:

Tokyo Engineering	Shimizu Construction
Nihon Seiko (NSK)	Toyoda Machine Tool
NEC	Fuji Electric
Murata Machinery	Toshiba
Komatsu	Daifuku

In July 1989, MITI published a report of the working group entitled "The future prospects of FA - from FA to IMS." The report summarized the status of FA implementation in Japan, identified problems to be solved for future developments, and suggested that the new term, IMS, replace the term FA, since FA does not cover the broad aspect of information technology involved in automating the total manufacturing process.

In 1990, MITI budgeted approximately ¥110 million to help fund the launching of IMS and to cover expenses for international committee meetings. In addition, a proposal was formulated within Japan's International Relations and Factory Automation Center (IROFA) to create a joint international research program into intelligent manufacturing systems that would include North American and European researchers in the field of production technologies. The chairman of the committee that developed the proposal was dean of the faculty of engineering at the University of Tokyo.

The IMS proposal had a 10-year planning horizon and recommended five broad research categories, including production system configuration technology, and production/control equipment and processing technology.

Based on previous knowledge about the IMS program and our conversations during the JTEC panel visit, no conclusive evidence was found that there have been as yet any results from the IMS initiative, or that any specific materials handling research work is underway that can be tied directly to IMS. Moreover, there was an (unofficial) indication that at least one of the initial industrial sponsors of IMS was likely to withdraw from its support of IMS. This could be interpreted as the result of the inability of the IMS proposal to produce a true international coalition.

Readers wishing to follow up on the status of IMS may contact the following:

IROFA
9th Floor, Darichi Makoao Bldg.
2-G-10 Iuamoto-Cho
Chiyoda-ku, Tokyo 101

Manufacturing 21

Manufacturing 21 is a consortium program initiated within the System Science Institute at Waseda University in 1987. In the beginning there were ten representatives from different companies plus faculty from the System Science Institute. Among the 10 companies forming the initial study group were:

Ajinomoto Co. (Food Processing)
Nissan Motor Co. (Automotive)
IHI (Industrial & Material Handling Equipment)
NEC (Computers and Electronics)
Toshiba (Machinery Division)
Tateishi Electric (Electric Generators)
Komatsu (Construction/Material Handling Equipment)

The program had a planned life of five years, through 1991, during which time at least three different industry/university study groups were formed.

Initial funding came from the Japan Machinery Federation as well as from the System Science Institute itself. Financial sponsorships eventually shifted to the participating companies, and the project became one of several multi-sponsor research projects of the System Science Institute.

The program was motivated by the belief that total quality programs and the just-in-time approach to manufacturing had begun to mature in leading Japanese companies. The rising value of the yen was also beginning to weaken what had been a strong competitive edge for Japan. It was believed that new initiatives were necessary in anticipation of unfavorable economic changes in both Japan and the world before the 21st century.

The objectives of the program became:

1) To develop a post- just-in-time (JIT) manufacturing enterprise.

2) To promote a highly decentralized, interactive form of management (not unlike efforts at self-directed work teams in the U.S.).

3) To develop truly integrated manufacturing software systems (CIM).

4) To attract the best and brightest students into manufacturing and retain their interest.

In 1992, work related to the Manufacturing 21 initiative appeared to be continuing at Waseda, including the work of two notable professors, one of whom (Teruo

Takahashi) is well known in the material handling and distribution community. The following views are among those driving current research:

1) Storage and distribution centers will again probably become decentralized, but more highly integrated, within both the manufacturing and distribution fields.

2) There will be a need for flexible, "minidecentralized," autonomous factories.

3) The process of evaluating and justifying large-scale capital investments is still in its infancy and needs much work in integrating enterprise impacts and assigning financial benefits.

4) There is a need to define the negative effects of system installations.

5) There is a need to define, evaluate and provide measures for system flexibility.

6) There remains a need to develop attractive working environments.

Two points are worthy of note in justifying what appear to be two separate initiatives (i.e., IMS and Manufacturing 21) addressing similar, if not identical, issues. The first point is that Manufacturing 21 appears to have predated IMS, and was an industry initiative unguided by MITI or any other Japanese government ministry. The second related point is that Waseda University is a private institution, while the University of Tokyo is a public institution. The distinction is important because private institutions find it very difficult to attract government funds and must rely almost exclusively on their own resources and/or those committed by private industry.

Given this, institutions like Waseda University and the University of Tokyo probably find it more difficult to collaborate. The result is two separate programs with a single purpose. There are undoubtedly some positive aspects of this scenario. However, one cannot help but think how much more energy could be focused on the objectives if there were to be a single funded program.

With regard to the level of research in both the IMS and Manufacturing 21 programs, the work to date appears to be very conceptual in nature. Virtually no basic research was found to be underway that can be tied directly to either program; certainly no material handling technology research was identified.

Robotized Building Construction

A third formal program has been underway in the System Science Institute at Waseda University that may have implications for material handling. The program is aimed at using robots (and perhaps other automated mechanisms) in the construction of buildings. The project began in 1982 and is still underway.

The project is a consortium undertaking, including sponsorship from the Japan Industrial Robot Association, various private companies, and Waseda University. The work being done in Japan under this program is not entirely unique since similar undertakings have been underway in the U.S., France, Germany, Finland, the United Kingdom and Israel.

There is at least some sharing of knowledge through international symposia on this topic. The first one of these was held at Carnegie Mellon University (in the U.S.) in 1984. The ninth one was held in Japan in 1992, and the tenth one is scheduled for the U.S. in 1993.

Japanese work in this area appears to be ongoing. During a visit to Waseda, a new building was observed under construction to house labs dedicated to the building construction robots program. There is probably very little being done at present with regard to conventional material handling. However, if the building construction process becomes automated, the issue of automated storage and material delivery will eventually have to be dealt with.

MATERIAL HANDLING RESEARCH

Virtually all basic research in Japan related to unit load material handling has been done in and by companies, not at public labs or universities. Moreover, the funding for these efforts has been from private corporate funds. Daifuku, the largest single supplier of industrial unit-load material handling equipment in Japan, returns about 4.5 percent of its annual revenues to R&D, and at least the three top suppliers maintain labs dedicated to basic research. Material handling is only one segment of the total business of the number two- and three-ranked suppliers as measured by dollar volume (Murata and IHI). It is assumed that the two companies can more easily leverage basic research through their other business units.

Daifuku is dedicated solely to the production of material handling equipment and systems, but because of its size it is nevertheless able to fund various types of research. This company has even created an independent research institute that is exploring the next generation of material handling equipment and systems.

None of the top three companies gave the JTEC team specific information concerning their current research. However, it was obvious from discussion and observation that one category of application commanding substantial research attention was material handling equipment for use in a clean room environment. In addition, the following areas are believed to be receiving attention:

1) Linear induction motor technology (LIM).

2) Magnetic levitation (suspension), especially in conjunction with LIM propulsion of carriers.

3) Artificial intelligence (AI) and in particular fuzzy logic as it relates to autonomous control (for AGVS, for example).

4) AI as it relates to diagnosing equipment/system failures and possibly corrective action.

5) AGVS guidance that does not rely on following a guidepath (e.g., buried wire or magnetic strip). In one case, an overhead (ceiling mounted) CCD camera may be under investigation as a means of effecting control and navigation. (This was unconfirmed).

6) Use of object-oriented programming in the design of new control systems. This probably qualifies more as development/application than basic research.

FUTURE VISIONS

This final section on research stretches the boundaries of unit load material handling research, but is worthy of mention.

There are several categories of development in Japan that have a bearing on material handling, or at least the distribution infrastructure. These include:

1) High-speed water transport vehicles.

2) Very deep tunnel (underground) multi-mode inter- and intra-city transport systems, including a concept called the geoplane (not unlike a jet aircraft in appearance) that will travel at jet aircraft speeds, plus other forms of tube transport systems that would rely on advanced magnetic and LIM propulsion.

3) City (building) structures that would rise far above the highest buildings currently in existence. Preliminary engineering designs are said to exist for both a 2,000-meter structure and a 4,000-meter structure.

In the case of item three, the principal concern related to material handling has to do with how to achieve vertical transportation in such tall structures, since conventional elevators would not be practical due to the size of the cables that would be needed. The most common answer seems to be in LIM technology that would operate in the vertical plane.

These concepts and visions may appear to be far-fetched, but some in Japan report them as being feasible by the year 2010.

CHAPTER 7

ADDITIONAL OBSERVATIONS

Thomas C. Day, Glenn J. Petrina, and Alvin R. Voss

OBSERVATIONS BY THOMAS DAY

This section offers observations on the state of material handling technology application in Japan from the point of view of a practitioner. This view takes the theory from academia, the latest development from the manufacturers, and the economics of a very competitive market place, selecting and applying solutions that will provide the enterprise with a competitive advantage.

The basic differences in both the labor and capital markets, coupled with land availability and cost, make comparisons of the application of material handling in the United States and Japan somewhat difficult. Nevertheless, there is much to be learned in making the comparison that will improve the application in both economies.

Project Approach

Most U.S. firms in need of a material handling system will turn to a consultant who will work with them to develop and design both the overall concept and a workable application with known systems and equipment. The Japanese firms visited by the JTEC panel tend to have a concept competition directly from the suppliers of the material handling equipment, followed by very early selection of the overall supplier, and then joint development and implementation of the design. This basic idea of competing on concept rather than price will undoubtedly be debated strongly by those who may consider this approach in the United States.

Some of the benefits of this approach include early selection of the major supplier(s) and the treatment of any design intangibles (noise control, work place esthetics, etc.) as an absolute in the process -- since they are the parameters given for the development of the competing concepts.

The Japanese designers of installations that the JTEC panel visited seem to believe that control equals accuracy equals reliability. Therefore the Japanese focus on control as a priority over systems integration. There also seems to be a concentration on automation (the ultimate in control) over service flexibility.

Justification

When very sophisticated Japanese material handling systems are viewed initially, most American observers have difficulty understanding the economic justification process used to bring these projects into fruition. This emphasizes the difference in the capital markets, land costs, and labor availability as well as the priority given to intangible benefits and control by the Japanese approach to these projects.

A direct and significant application to the U.S. is the use of information systems (IS) technology to leverage capital employed in a major project. This is evident through the focused application of material handling technology on very small applications (e.g., AS/RS 2 meters high x 10 meters long) that have been defined through IS. Several different technologies may then exist economically in the same facility with the computer directing activity to where it is most productive.

Relative to comparable U.S. firms, there seems to be a higher level of capital available in Japan. Virtually all of the Japanese distribution sites JTEC visited noted a significant shortage of labor, and seemed to be trying to make the distribution environment a more desirable place to work. Despite these efforts, the panel was encouraged to believe that culturally distribution centers are not thought of as appropriate work. Therefore there continues to be a significant effort to reduce the labor content of distribution functions.

Mechanization/Control Systems

The high degree of mechanization and sophisticated equipment control systems found in Japan seem to be the result of the concept competition project approach, which minimizes the opportunity to have competitive approaches to subsystems or to compromise any of the intangible design parameters. The systems observed worked well in concert -- that is, with a very high level of reliability.

Information Systems Integration

Information systems that this panel observed were well integrated into the material handling application, and within the facility they served. They did not, however, seem to have a great deal of flexibility in either the mechanical material handling equipment or in the systems that supported them. Again, this was seen as the tradeoff of control over flexibility and automation over service.

Conclusion

The blend of ideas from both Japan and the United States may well hold great promise for those U.S. companies with the vision to bring it to fruition. This will mean the development and application of small material handling systems that can target specific opportunities to provide productivity enhancements. Along with this must be an investment in IS technology that yields the flexibility and service needed to be competitive in the U.S. marketplace. Where the U.S. does not have the very high land cost and labor shortage characteristic of Japan, it should apply the investment to the systems integration necessary to meet the rapidly changing world the U.S. competes in.

OBSERVATIONS BY GLENN J. PETRINA

There are significant differences between U.S. commercial warehousing operations in general and those of the Department of Defense (DoD). Obviously, the DoD warehouse operator does not select what to store; furthermore, the operator often cannot select the quantity or duration of storage.

Many critical weapon system parts cannot be manufactured to satisfy an immediate demand and must, therefore, be stored in greater quantity. Even when the United States retires a weapon system, parts must be stored to satisfy demands or contract sales to foreign militaries.

These requirements have created a need for storage of large inventories of very diverse items with very low demand histories. The Defense Depot Richmond Virginia (DDRV) is typical, storing electronics parts, clothing and 55 gallon drums of antifreeze. DDRV is currently storing over 750,000 NSNs (SKUs), but only shipping approximately 10,000 (MRO) orders a day.

Labor savings are also an often-used justification for DoD, but for a slightly different reason. In recent times, personnel dollars are becoming severely restricted. If personnel reductions are not mandated, then additional missions must be accomplished with the same work force. For this reason, several of the systems or application features found in Japan are good candidates for usage in DoD or commercial operations.

- **Smart Card Picking Systems** - Smart cards are being used in the U.S., but the Japanese have a slight edge in their applications. By downloading pick information to cards, they can reduce or eliminate the need for a more costly radio frequency system. Frequencies can also be difficult to obtain in populated areas.

- **Robotic Forklifts** - There is a good potential for use of this system in cold storage or any other environment that, because of physical conditions, is difficult for people to work in. Large productivity gains are very possible.

- **Laddermatic** - DLA has two rotary rack systems that are used for random sortation. This device appears to have applications to increase throughput of a rotary rack.

- **Tier Picker** - This device can reduce the need for personnel. There are limitations in that the cases must be uniform and sturdy, but there are good possible applications.

- **Dock Management** - The vehicle control systems at the Tokyo Post Office, Suntory and Okamura are excellent and superior to anything seen in the U.S. Dock operations are often overlooked as being outside the prime area of attention.

- **Ergonomics and Esthetics** - The Japanese attention to detail is evident in many areas. Lift assistance devices are extensively used. Using larger lettering on signs to accommodate an older work force, providing heated floor mats for workers, and color coordinating work areas and uniforms are all used to provide a more pleasant and consequently a more productive work area.

- **Service** - The Japanese have a customer-oriented attitude that affects all designs and decisions. Their post office delivers gift-wrapped packages that include strings or ribbons and even live plants. Their sortation system is designed to handle these without damaging the product. At the Toyota distribution facility, new vehicles coming from the factory are cleaned and again checked for such items as headlight adjustment.

The Japanese are leading the U.S. in these areas because their conditions or situations demand it. The services area is most significant: The Japanese know their customers and what they need or want, and ultimately find a way to provide it. As the United States shifts away from a manufacturing base to a more service-oriented economy, we must learn that lesson.

OBSERVATIONS BY ALVIN R. VOSS

Background

Having been asked to participate on the JTEC evaluation panel for material handling, I set out to try to get a better understanding of how the Japanese approach designing, justifying and implementing material handling projects in their manufacturing and distribution processes. I wanted to gain insight into how they go about improving their processes before they mechanize/automate. Once in Japan, it became clear that any in-depth analysis of how their processes are changed for optimization would be almost impossible. There just was not enough time during each half-day visit to go into details about how their operations worked before being mechanized/automated. A lot of time was spent gathering comparative data so that overall comparisons could be made. However, based on my own observations I have come to the following general conclusions about how the Japanese fine tune their processes:

Observation 1: Keep it Simple and Flexible

Many of the Japanese systems are not complex. Basic material handling concepts are used to achieve productivity improvements. There do not seem to be too many "bells and whistles" added to the systems.

In its effort to show the greatest possible return on investment, the United States frequently adds marginal activities or operations to material handling systems, purportedly to help sell them. Often this complicates the system more than is necessary, making it vulnerable later when the extra activities disappear or are changed. The system should not only be simple, but also flexible.

Observation 2: Fine Tune Your Current Process

The Japanese have no problem taking a small, isolated, stand-alone process, fine-tuning it, and then applying the right amount of equipment/automation. The panel saw many examples of this in our visits to both manufacturers and users of material handling systems.

Until a few years ago, U.S. users typically did not fine tune their manual distribution and manufacturing processes. Instead, the typical mode was to take an existing process and apply complex material handling concepts and equipment. This in effect caused extra capital investment in systems and equipment that were not necessary.

Reducing cycle time is one of the best ways to fine tune a process. The shorter the cycle time the less inventory needed to achieve the same customer satisfaction. The Japanese are very good at reducing cycle time. This was evident from the material handling systems installed. The systems all work efficiently. To reduce cycle time, product/output quality must be examined. Every work activity has a customer and a cycle time that can be reduced by simplifying the process, eliminating time that does not add value and eliminating and preventing defects. Defect elimination and cycle time reduction are closely linked in that the shorter the cycle time the less opportunity for introducing defects into the process. Time spent reworking product or redoing output increases the cycle time. Some examples of activities that increase cycle time and induce defects are: correcting errors, waiting for work, batching information, inspecting for quality and movement between departments/ noncontinuous processes. These are all activities that appear to have been eliminated in the systems that the panel saw in Japan.

Some ways that tasks can be made more efficient are:

- Understanding customer requirements
- Empowering employees
- Providing timely information/communications
- Synchronizing activities between processes/departments
- Providing proper tools and materials
- Using preventative maintenance

Reducing inventory also helps simplify the receiving, storage and issuing of parts in the manufacturing and distribution functions. Implementing just-in-time concepts on high dollar and/or large cube items goes a long way towards simplifying the warehouse and manufacturing floor processes. As noted above, storage is not a value-added activity. So installing complex material handling systems to mechanize this activity before simplifying it is not the best approach.

Observation 3: Continuous Improvement

The Japanese are always looking for ways to improve even the smallest detail. Systems that have only been in existence for a short time are reviewed for future improvement.

No matter what material handling system is implemented, it is essential that all processes be continuously improved. With continual improvement, deciding when, where and how to mechanize/automate will be a much easier decision. It will also mean that less money will be spent to be more efficient. This is a day-in and day-out process. One cannot wait until major changes are needed to solve growth problems, provide new product lines, and so forth. The ability to remain competitive requires constant improvement in all aspects of a business.

Summary

In conclusion, in the U.S. manufacturers and users must work together to achieve the best possible solution to a material handling problem. Following the steps described above will help make the final solution better and longer lasting.

The United States can still excel in the development of devices for assisting workers in repetitive jobs that place tremendous physical stress on their bodies. I saw nothing in Japan that would indicate that the Japanese are researching or spending much time in this area. One reason may be that their work force, in the industries that utilize material handling equipment, consists mostly of healthy males. There is no urgency to research, design and sell equipment for individual workers to use in their repetitive jobs lifting 20-pound loads or continually bending or reaching for items in low or high storage areas. Given the current environment in the U.S., where workers are increasingly becoming aware of the impact of repetitive work on their bodies, the material handling industry could provide a great service by developing devices to solve this problem.

APPENDICES

APPENDIX A. PROFESSIONAL EXPERIENCE OF PANEL MEMBERS

Edward H. Frazelle, Panel Cochair

Edward Frazelle is director of the Logistics Institute at Georgia Institute of Technology, where he was formerly employed on the faculty of the School of Industrial and Systems Engineering and the Material Handling Research Center. His experience in industry includes management and engineering positions with CSX Logistics Information Services, General Motors, Coopers & Lybrand, and Tompkins Associates. He is a past president of the International Material Management Society and a former recipient of the Council of Logistics Management's Doctoral Research Grant, the Warehousing Education and Research Council's Burr Hupp Fellowship, and the Material Handling Institute's Graduate Fellowship. He recently completed a text entitled *Material Handling Systems and Terminology*.

Richard E. Ward, Panel Cochair

As Vice President of the Material Handling Industry (1986-present), Richard Ward represents the interests of that association's two primary divisions, the Material Handling Industry of America (MHIA), and the Material Handling Institute (MHI). In addition to his role as head of education for both divisions, and being a senior administrative officer, he also serves as MHI's Managing Executive for the Automatic Guided Vehicle System (AGVS) industry, the Automated Storage and Retrieval (AS/RS) industry, and its Integrated Systems and Controls Council. Dr. Ward is also the staff executive for the College Industry Council on Material Handling Education (CIC-MHE) and is a member of the Board of Directors of the Material Handling Education Foundation. Prior to his present position, Dr. Ward held a variety of positions both in industry and in academia. The most recent of these was as a Professor of Industrial Engineering at West Virginia University (1976-1986).

James M. Apple, Jr.

James Apple works as a consultant to Vanderlande Industries of Holland. Prior to that, he was a Partner with the SysteCon Division of Coopers & Lybrand, responsible for consulting engagements in the design of material flow systems in logistics networks, warehouses and manufacturing operations. He is Director of the Institute of Industrial Engineers' annual Material Handling Management Course, and a member of the Alumni Advisory Board for the School of Industrial and Systems Engineering at Georgia Institute of Technology. He is author of chapters relating to material handling and warehousing in the *Production Handbook for Industrial Robotics, Warehouse Management Handbook* and *Profitable Logistics Management.* Prior to joining Coopers & Lybrand, he was an Industrial Engineer with IBM, Supervisor of Plant Layout at Oldsmobile Division, General Motors, and Executive Vice President of an automotive parts remanufacturer. In 1990 he was presented with the Reed-Apple Award for his contributions to material handling education.

Thomas C. Day

Thomas Day is currently a consultant in logistics and distribution for Day and Associates. Previously he was Executive Vice President Operations for Hanover Direct, a $600 million catalog retailer with 18 different catalogs generating more than 10 million customer orders annually. Prior to his position at Hanover, he served as Senior Vice President Logistics and Operations for the Timberland Company, and for 13 years at L.L. Bean, Inc. While at L.L. Bean, Mr. Day was Vice President, Fulfillment Operations during the time that the company grew from $60 million to more than $600 million and set the standard for world class service in the catalog industry. Mr. Day received his B.S. degree in Industrial Engineering and his M.B.A. from Syracuse University. He also completed the Advanced Executive Program at Northwestern University's Kellogg School. Mr. Day worked with Xerox in the early 1980s as the company developed competitive benchmarking into an effective process improvement discipline.

Glenn J. Petrina

Glenn Petrina is the Chief of Engineering for the Depot Operations Support Office (DOSO). He has served in this capacity for three years, having previously been a Design Engineer, Program Manager, and Deputy Chief of the office. DOSO is the designer/integrator of automated/mechanized material handling systems for the Defense Logistics Agency. Prior to his DLA assignment, he served as a construction and contract manager for the replacement of Lock and Dam 26 on the Mississippi River and new military family housing construction in Germany and Italy. Mr. Petrina received his B.S. degree in Mechanical Engineering from Vanderbilt University and an M.S. degree in Civil Engineering from Pennsylvania State University. Mr. Petrina is a retired U.S. Army Corps of Engineer Lieutenant Colonel and is a registered professional engineer.

Alvin R. Voss

Alvin Voss is a Senior Engineer in IBM's Worldwide Distribution Engineering Services (WDES) department. He is presently responsible for reviewing and approving IBM's capital expenditures in Distribution Centers and Material Distribution Centers worldwide. He is also involved in Packaging Engineering projects related to defect elimination and benchmarking. Prior to joining the WDES department, Mr. Voss was Distribution Engineering Manager at IBM's AS400 manufacturing facility in Rochester, Minnesota, where he received several IBM Awards for the best environmental packaging designs in the corporation. Mr. Voss has also spent time as a Quality Engineer on the AS400 and as an Export Compliance Expert for IBM Rochester. Mr. Voss spent three years working in Frankfurt, Germany at IBM's Distribution Engineering Service Center, where he was responsible for european distribution projects and packaging engineering.

Howard A. Zollinger

Mr. Zollinger has more than 35 years of industrial management and technical experience in the U.S. material handling industry. He has both bachelors and masters degrees in electrical engineering, plus additional post-graduate work in business and management. He also hold 16 patents, 15 of which are directly related to material handling equipment and systems. Mr. Zollinger's broad spectrum of accomplishments, which led to his forming his own consulting practice, is derived from years of heading the material handling activities of one of the world's largest suppliers of material handling systems and equipment, one of the nation's largest conveyor systems companies, and one of the nation's most prestigious electrical corporations. His groups have studied and implemented large automated systems in the United States and Europe. As President of Zollinger Associates, he is using his personal experience to consult and plan systems for North American and European clients.

APPENDIX B. SITES VISITED BY JTEC PANEL

Banyu Pharmaceutical Co., Ltd.
Meguro-ku, Tokyo

Pola Cosmetics, Inc.
Shizuoka

Murata Machinery, Ltd.
Automated Systems Division
Inuyama, Aichi

Suntory
Kisogawa Plant

Suntory Tonegawa Brewery
Gunma-Ken

Daifuku Co., Ltd.
Komaki Plant
Komaki-shi, Aichi

ORIX Rentec Corporation
Tokyo

Fuji Logitech Inc.
Fukuroi Branch
Shizuoka

Ishikawajima-Harima Heavy Industries
Co. Ltd.
Tokyo

Yamatane Oi Distribution Center
Tokyo

Nippon Shuppan Distribution Center
Tokyo

Ohki Distribution Center
Ageo

Yokohama Distribution Center
Okamura Corporation

Sun Distribution Center
Nagasakiya

Nichi-Rei (Funabashi)
Nichirei Corp.

Shin Tokyo Post Office
and Tokyo Parcel Post
Tokyo

Chiba Toyopet
Chiba Prefecture

APPENDIX C. SITE REPORTS (JTEC Site Visits)

Site:	**Banyu Pharmaceutical Co., Ltd.** **10-34 Shimo-Meguro 3-Chome** **Meguro-Ku, Tokyo 153**
Date:	April 6, 1992
Report Author:	R. E. Ward

ATTENDEES

JTEC:

R. Ward
H. Zollinger
A. Voss
L. Martin-Vega
B. Williams

HOSTS:

Masaji Nakano	Manager, Shipping Sec., Tokyo Distribution Ctr.
Tohru Hirose	Ass't. Manager, International Marketing & Sales Murata Machinery Ltd., Automated Systems
Hirohito Nakano	Murata Machinery, Automated Systems

BACKGROUND

The Banyu Distribution Center is a one-year-old, $10 million facility that is highly automated and tightly integrated from the perspective of both material and information flow. The material handling equipment in the center, including computers and controls, represents approximately one-half of the total investment in plant and equipment.

Banyu is a pharmaceutical manufacturing company. Among its products are drugs licensed from the U.S. company, Merck. It is one of approximately 20 Japanese drug manufacturers. Banyu's annual revenue is approximately $750 million. The site visited by the JTEC panel accounts for approximately 45 percent of this ($338 million), with a capacity of $1 billion, or a 10-year design life.

This distribution center is one of two owned and operated by Banyu, and is one of approximately 50 throughout Japan. The hosts explained that both the size and level of automation in the facility is fairly typical of that found in distribution centers throughout Japan. However, this one was among the most modern and employed some unique features in both mechanical automation and information integration.

Pharmaceutical logistics in Japan flow from manufacturers to distribution centers, such as the one visited, from there to numerous wholesalers, and finally from wholesalers to private retail outlets. Orders are placed from the retailers to the wholesalers, and the wholesalers in turn place orders with the distribution center. The distribution center does not see the retail order.

The center JTEC visited handles triple the volume of the center it replaced, with approximately two-thirds the number of people, which at the time of the visit consisted of fifteen warehouse personnel, five office personnel and one manager.

On an average day, the distribution center makes shipments to 120 wholesalers out of a total of 250 that it serves. Average daily shipments are 1,000 cartons, with a peak of 2,500. The maximum shipping capacity is 3,000 cartons per day. The current level of shipment amounts to four delivery trucks outbound per day, with one inbound truck from manufacturing per day. Clearly, the outbound trucks on average are not fully loaded.

Other significant statistics include a claimed 100 percent total shipping accuracy and a 100 percent total inventory accuracy; both of these statistics were accounted for largely because of the highly integrated material and information flow control, and the fact that to achieve 100 percent order filling accuracy, the order is checked twice prior to final packing and shipment. The order-to-shipment cycle is one day.

MATERIAL FLOW AND TECHNOLOGY EMPLOYED

The best way to describe flow in the distribution center and the level of automation technology employed is to use an isometric illustration of the distribution center (Fig. Banyu.1). Various statistics concerning equipment and center operation are incorporated in the discussion that follows.

Out of a total of 435 line items, 90 percent of which are produced by Banyu, 21 are considered high-volume movers and are picked for shipment in case-load quantities directly off pallets; 250 are medium volume movers and are loose picked for shipment from case flow racks; and 150 are slow movers. The latter are case stored on static shelving and loose picked for shipment.

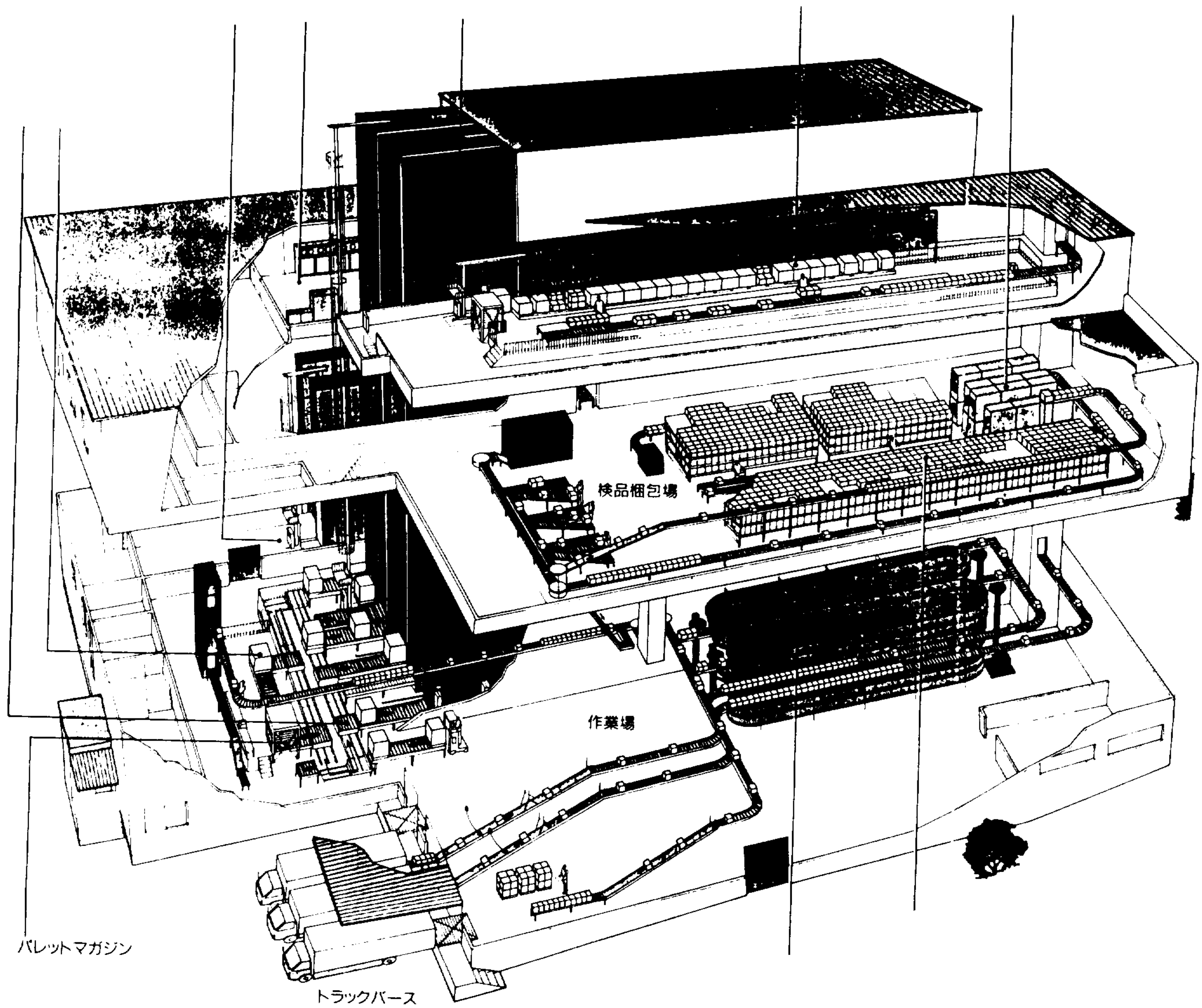


Figure Banyu.1. Banyu Distribution Center

All items received at the distribution center arrive, non-palletized, in their original cases. High-volume movers are hand-palletized and delivered to a unit load AS/RS P&D station by one of only two fork trucks in the center. The loose case delivery is explained largely because of the small and somewhat narrow trucks used both for receipt and delivery. In the case of delivery, a single shipment to a wholesaler consists, on average, of less than a pallet load.

As seen in Figure Banyu.1, the distribution center consists of three floors with the three-aisle unit load AS/RS in the background. The third floor is dedicated to 22 permanent floor-level pallet picking positions, 21 fixed positions for case picking of the high-volume movers, and one spare position for special situations. Each picking position is backed by two pallet reserve positions on single-deep selective racks.

Pallets arrive on the third floor by way of an AS/RS crane, which deposits the pallets, through a passageway, onto a P&D station at the midpoint of the 22 picking positions. A much smaller, dual shuttle automated stacker crane manages the storage retrieval and sorting of full and empty pallets for case picking at the 22 positions.

Picking on the third floor is facilitated by a computer-aided pick director. A terminal screen displays picking direction at two zones along the line. This is aided by pick-to-light displays over each pallet position. A portion of the display then shows the number of cartons remaining, which the operator can quickly verify by visual inspection.

Picked cartons move along a conveyor to a vertical carton elevator. Just prior to the elevator a bar-coded shipping label is automatically attached to the carton.

Split-case picking takes place on the second floor: medium-volume movers from carton flow racks and slow-volume movers from shelving as mentioned earlier. As was the case on the third floor, picking is facilitated by the same type pick director and pick-to-light displays. Picked items for a given order are placed into a standard plastic tote. When the order is picked, a bar code shipping label is generated and placed on the tote, which is then routed to one of three picking lanes on the second floor (visible to the left of the picking flow racks).

Packing is quite sophisticated, incorporating automatic order checking by way of a grocery checkout counter-type bar code scanner, coupled with a video terminal display of packing progress and order accuracy. Prior to packing, the computer calculates the required packing carton size.

Following packing, cartons are automatically transported to the first floor by way of vertical carton conveyors and staged for shipment in the same set of rotary racks.

When a delivery truck arrives, high volume full-case lots are picked from the third floor. These cases are dispatched through a vertical elevator to the first floor. At the same time, the remaining part of the truck's order (low volume and mixed cases), which has been prepicked and staged in the two rotary rack carousels, is automatically selected. These cases are combined with the full case lots from the third floor and loaded onto the truck. Although loading is done manually, the process is aided by extendable conveyors that rotate down from overhead while loading is in progress.

The daily work schedule is 8:45 a.m. to 5:30 p.m., five days a week, for a total of eight hours work time (approximately 1,900 hours per year per person). Receiving takes place in the morning, and picking takes place throughout the day. The shipping cycle starts around 2 p.m.

ADDITIONAL OBSERVATIONS

Items requiring special, environmentally-controlled storage conditions are staged on a single aisle unit load AS/RS that is visible behind the main and taller AS/RS. Pallets are delivered by fork truck through an automatic door, directly to the end-of-aisle P&D station. In the case of the main AS/RS, a single P&D station (visible to the side and in the foreground) serves all three aisles. A sorting transfer car mechanism that is a derivative of the CarTrac system originally designed by the U.S. company, SI Handling, manages the flow into and out of the AS/RS automatically.

The planning, construction and installation of the Banyu distribution center spanned approximately two years. The material handling portion of the project took approximately 18 months. Three equipment vendors were originally invited to submit concept proposals. One vendor was selected based solely on the proposed concept and the vendor's reputation. Budget prices were not established until after the vendor was selected.

A fact worthy of special note was the customer's role in system development and implementation. Not only was there an apparent strong vendor/customer team relationship, but the customer was responsible for the development of the facility-level control software that both tracked inventory and directed order-filling operations. Machine-level controls and integration were provided by the supplier. The supplier and integrator in this case was Muratec (formerly known in the U.S. as Murata).

With such a high degree of mechanized handling and automation, the subject of maintenance was discussed. From Banyu's point of view, maintenance is not a problem, and they have no maintenance people on their staff. Instead, they rely on yearly maintenance contracts with the supplier. Twice yearly preventative maintenance checks are conducted. Extraordinary maintenance needs are handled by one of many supplier service centers spread throughout Japan.

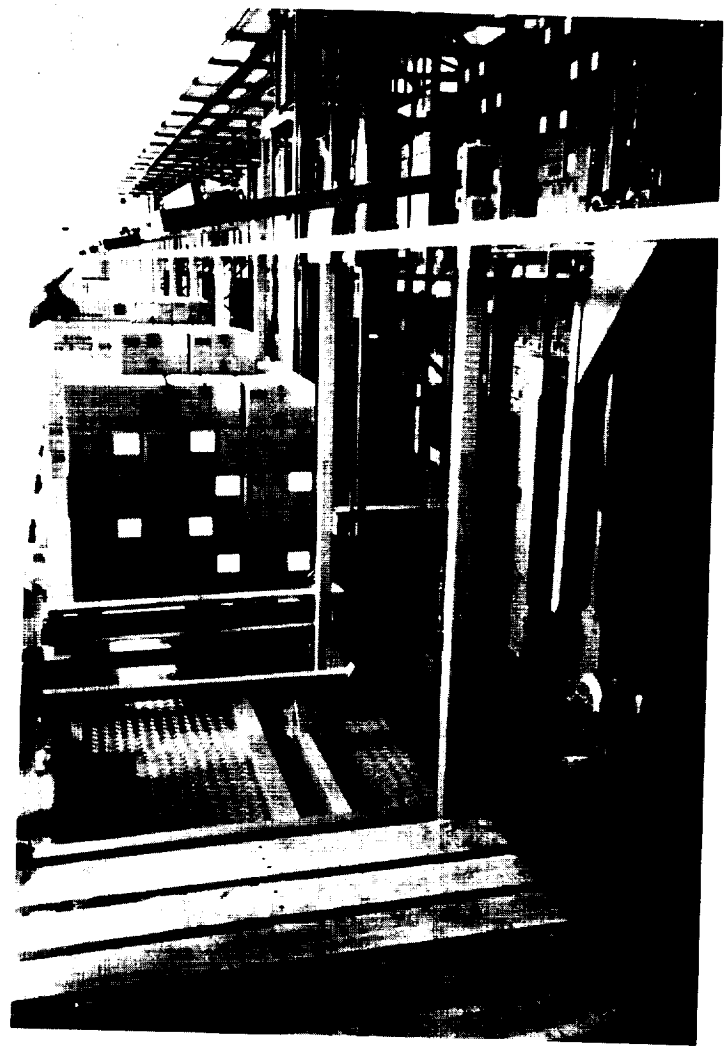
With regard to the logistics network, orders are computer downlinked to the distribution center from a central and remote business computer. The distribution center's inventory control system selects the wholesaler's order and directs instructions to the material handling system. Wholesalers stock upwards of 20,000 different SKUs and, we were told, are fairly traditional warehouses with little or no mechanical automation. We were also told that Banyu currently stocks upwards of two months' supply for its wholesalers, which is a fairly large cushion. Banyu states that they intend to reduce the two months to a level under one and a half months. Currently approximately 30 percent of the month's order volume is filled in the first three days of each month. It was explained that it is Japanese practice, at least in the case of pharmaceutical distribution, to be safe rather than sorry, which promotes a high safety stock at the distribution center level.

SUMMARY

While there does not appear to be any ongoing research at this site, a great deal of automation technology has been employed in an effort to reduce labor costs and improve both order and inventory accuracy. The only developments believed to be underway are in the area of business system software. Nevertheless, the distribution center is well run and highly effective, and appears to have met the goals established when it was first designed.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Illustration of pick-to-light split pallet case picking (Fig. Banyu.2, Left) and accompanying twin shuttle stacker crane (Fig. Banyu.3, Below) used to service the 21 picking positions at Banyu Distribution Center.



Site:	**Pola Cosmetics, Inc.** **2080-1 Aino, Fukuroi** **Shizuoka 437, Japan**
Date:	April 9, 1992
Report Author:	R. E. Ward

ATTENDEES

JTEC:

R. Ward
H. Zollinger
A. Voss
L. Martin-Vega
B. Williams

HOSTS:

Nobuhiko Yamamura	General Manager, Nishi-Nihon Distribution Ctr.
Yuji Ohkubo	Manager, Product Distribution Department
Fukazawa Shigema	Assistant Manager, Nishi-Nihon Distribution Ctr.
Edward Ray	(Interpreter), Engineering Dept., Komaki Works Daifuku Co., Ltd.
Yoshiyuki Onoue	Manager, Section 2, FA and Material Handling Systems Sales Division, Daifuku Co., Ltd.
Shin Suzuki	Logistics Consultant

BACKGROUND

Pola Cosmetics is a manufacturer and distributor of cosmetics that operates much the same way as Avon in the U.S. The company started in 1929 and today has an annual sales volume of approximately $1.8 billion. In 1982, the company added jewelry and women's clothing to its line, but cosmetics still accounts for 70 percent of total sales.

Like Avon, Pola sells to the final customer through sales affiliates who make personal visits to the customer's home. Pola has no retail store outlets. Orders shipped from Pola distribution centers, such as the one the JTEC panel visited, are destined for 69 sales outlets from which 6,600 sales affiliates receive their merchandise.

Pola began a logistics restructuring plan in 1979 that led to the eventual consolidation of nine major distribution centers into four, and the networking of all sales outlets. The center visited (one of the four) services western Japan and 2,600 affiliates (each affiliate also works with approximately 20 additional home call sales persons each).

In October 1991, the company launched a material handling strategic plan that had as its goal a restructuring of the entire order delivery system. Specific objectives associated with the plan included a reduction in order delivery costs, improved service, and a reduction in the order-to-delivery cycle time to three days. The original order cycle time was seven days, and inventory turnover in the distribution center was four times per year. The order cycle time in the warehouse is now one day (receipt to shipment), and the inventory turnover is twelve times a year. With further improvements planned for manufacturing, the company hopes to achieve an inventory turnover rate of twenty-four times per year.

Our hosts described what they had achieved as being a direct result of their "*Kaizen*" philosophy. When asked what they meant by *Kaizen*, they described it as being a desire to improve their past process and performance by involving workers from the bottom levels up, and that this practice was ongoing. They added that their desire was, and is, to learn how to synchronize all functions. To them, "...it's a way of thinking about things."

MATERIAL FLOW AND TECHNOLOGY EMPLOYED

The Pola site takes in a little over 17,000 m². However, the warehouse itself occupies only 7,400 m² out of a total building footprint of 8,646 m². The warehouse is a one-story structure (Fig. Pola.1).

At present the warehouse stores and distributes approximately 900 line items, with an eventual capacity for 1,200 lines. Area 1 in the layout is reserve pallet storage. Area 2 includes flow delivery racks for split-case picking of high-volume line items. Area 3 incorporates bin shelving for the low-volume movers. Between area 3 and the truck docks are 12 parallel order-packing lines. All areas in the facility are interconnected by automatically controlled belt and roller conveyors for the movement of cases from reserve storage; the circulation of full and empty totes between areas 2 and 3; and, finally, packed cartons.

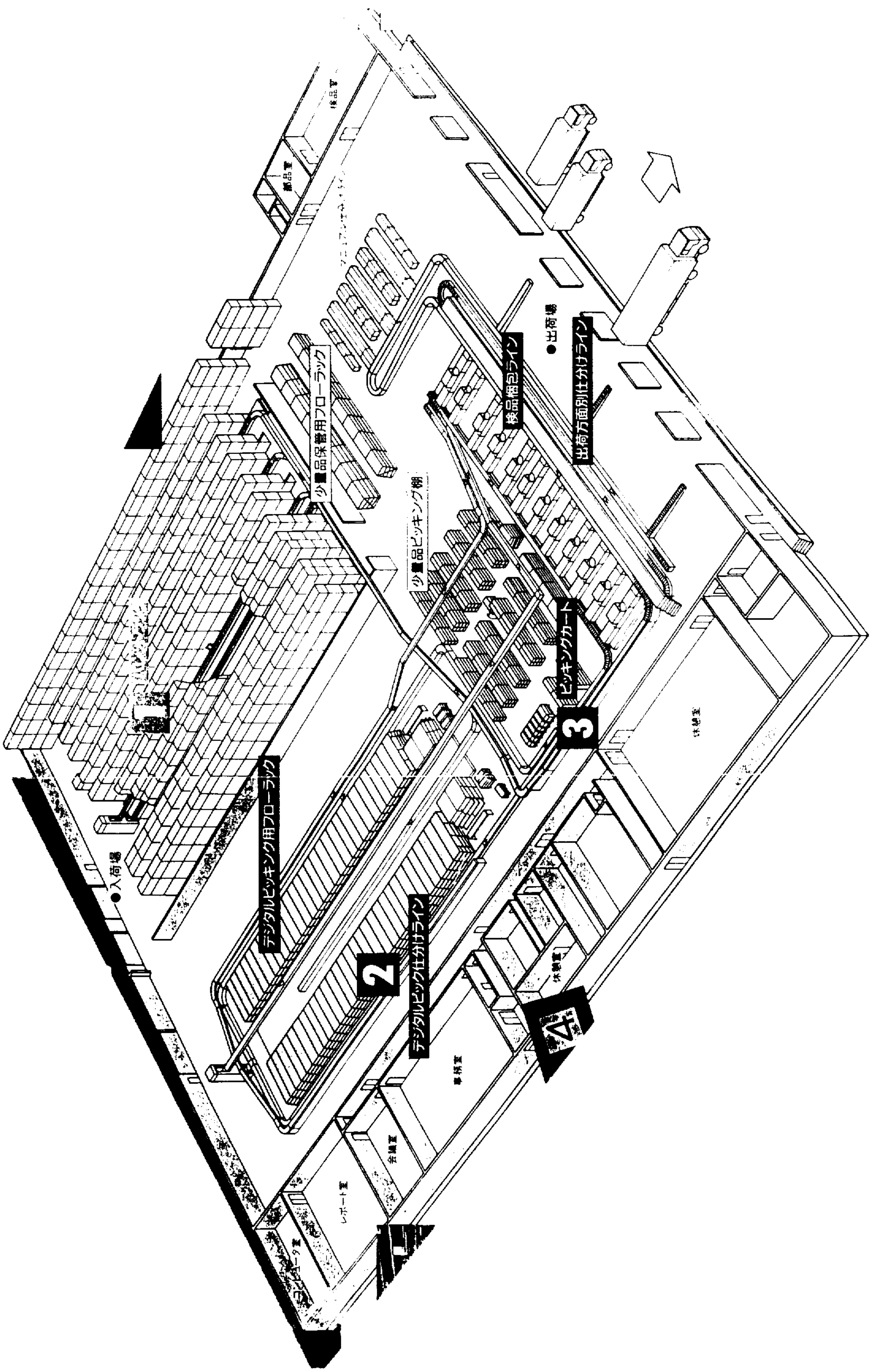


Figure Pola.1. A Pola Distribution Center

All goods arrive at the distribution center on pallets direct from the adjacent manufacturing plant. Delivery is by way of fork trucks using covered passageways. The pallets are stored four high, single deep in selective racks using narrow aisle turret fork trucks. Manual case picking for the purpose of replenishing areas 2 and 3 (split-case order picking) takes place at the first (floor level) and second (mezzanine) levels of the pallet rack in every other row.

Orders are transmitted to the site host computer until 4 p.m. each day. Cases are then batch picked overnight to replenish stock for order picking the next day from both the flow racks and the bin shelving. Although the cases are picked that night and routed to the appropriate order picking area, the picking lanes and shelving are not replenished until the start of the next day.

During the night the host computer also calculates the number of totes required for each order, plus the number of packing cartons needed, as well as the size required for each order. The empty totes are then pre-staged for the start of picking the next day, as are cartons at the packing stations.

Area 2 consists of two identical picking lanes. Case replenishment occurs between the two lanes. Picking therefore takes place to the outside. There are a total of 270 case openings in each picking lane (i.e., a capacity of 270 fast-moving line items).

The face of the picking lane is divided into zones. On the replenishment side of each zone is a light. When a lane is nearly empty, the controlling computer turns on the light and recorded music as a signal to replenishers. Using push buttons, the replenisher informs the computer that replenishment has been completed.

The actual split-case picking from the flow racks is facilitated by computerized pick directors and pick-to-light displays at each picking face. There is also a belt conveyor segment in the front of each zone, exactly the same length as the zone. Picking and flow down the line is highly synchronized with electronic, push button interlocks at both the picking face and beside the conveyor segment, which makes picking errors all but impossible. Totes being filled for each order progress down the picking lane as they are automatically released from each zone. Another interesting (human factor) feature of the picking zones is that for the comfort of pickers there is a heated, rubber floor mat that occupies the entire floor space area of each zone.

While picking of the high-volume items takes place in area 2, the computer has synchronized the picking of low-volume movers from the bin shelving in area 3. There are 640 bin faces in this area. A unique, electronic picking cart is used by pickers in this area.

The synchronized orders are downlinked to a local PC in area 3. A picker, ready for the next picking cycle, inserts an IC Ram card into the PC. The PC downloads picking instructions to the card. The operator then inserts the card into a reader on the picking cart. The card is equipped with a controller and small video display panel. The panel first displays a layout of the entire bin shelving area, highlighting the shelving faces where picks are to take place. The picker can then choose to begin at any aisle he/she wishes.

As the cart enters an aisle being pushed by the picker, infra-red sensors on the cart detect the aisle, and the video display immediately changes to show a blown-up picture of the aisle. The picking faces and the bins that need to be picked from are highlighted, with correct quantities shown for each order. Each cart is equipped to handle eight orders in each order cycle (i.e., eight bins per cart). Successive video displays and pick-to-light displays (on the shelving and the cart bins) allow the picker to progress through the picking cycle quickly and virtually without errors.

There is a small order accumulation area (using bin shelving) for picked low-volume items. Picked items for a given order (in plastic bags) are manually merged into the totes that come from area 2. The accumulation area is small due to the careful, synchronized picking.

Completed orders progress to packing where the packing count is electronically checked twice by way of photo cells. One person removes items from each tote, placing them on a conveyor. Two sets of photo cells count pieces, allowing the person emptying the tote and the person doing the packing to affirm the correct count against the packing slip. Items to be packed are presented to the packer on a revolving turntable approximately one meter in diameter. The turntable and the packing station layout were designed by Pola personnel.

On an average day the distribution center will process 1,200 orders and ship 1,200 cartons with an average of 50 pieces per order. On a peak day, the distribution center will pick and ship 110,000 items. Shipment is by way of common carrier, with an average of three trucks per day.

The center relies heavily on so-called part-time personnel (100 total). Ninety-five people work 6 hours per day; five work 7 hours per day. Eighteen full-time people (supervisors and foreman) work 7 3/4 hours per day. In addition, there are 3 computer operators and 3 managers. There are no maintenance personnel on site.

SUMMARY

While the horizontal and vertical conveyors constitute the only mechanical automation in the warehouse, there is a very high degree of information integration that ties the picking and material flow together. Nevertheless, the picking along the flow racks and the picking carts in the bin shelving area are highly sophisticated. The technology employed is clearly expensive. However, the point was reinforced more than once that the driving force was an error-free operation manned by unskilled labor.

Pola has improved its order accuracy tenfold as a result of the recent change, from 4 errors in 100,000 to 4 errors in 1,000,000. The boasted Japanese average is 2 to 3 errors per 10,000.

Future planned developments for the Pola distribution center include a redesign and layout of the packaging area. This writer observed that because the computer does such a good job of estimating shipping carton size, the packing process is slowed somewhat by the packer having to figure out how to fit items in the carton. A possible research project (albeit somewhat theoretical) would be for the computer to figure out the packing sequence and to somehow transmit that knowledge to the packer in a format that is easy to understand and use.

Lastly, the Pola visit reconfirmed that consultants are used very little in Japan for the design of logistics and distribution centers. The Pola project made use of a consultant only to review the concept proposals made by the competing suppliers, and to suggest refinements that could possibly improve what was being proposed.

Illustration of zoned belt conveyor and operator controls (Fig. Pola.2, Left) that are tied into gravity flow rack picking bays (Fig. Pola.3, Below) at a Pola cosmetic distribution center

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Figure Pola.4. Intelligent picking cart used at Pola Cosmetic Distribution Center

Figure Pola.5. One of the several screen displays used to direct the order picker

Site: **Suntory**
Kisogawa Plant
30 4 Aza Kakuike
Inuyama City
Aichi-Ken 484, Japan

Date: April 8, 1992

Report Author: R. E. Ward

ATTENDEES

JTEC:

R. Ward
A. Voss
L. Martin-Vega
B. Williams

HOSTS:

Shida Teruaki	Distribution Center Manager
Yasuyuki Tanaka	Murata Machinery, Ltd., Marketing Sales

BACKGROUND

Suntory is a very large food products company with worldwide operations. Suntory is probably best known as a brewer of premium beers and a producer of premium whiskeys. However, it also produces other beverages, and very recently launched into pharmaceuticals.

The site the JTEC panel visited was a combination whiskey production plant and adjacent distribution center. It was an unplanned visit arranged by Murata Machinery so that the team might see some of Murata's equipment in use. The first part of the afternoon was spent at Murata's headquarters. The last part of the afternoon was spent at Suntory, accompanied by Murata personnel. Suntory was approximately a 20-minute drive from the Murata site visited at the start of the afternoon.

The warehouse stores and ships 1,957 different SKUs broken down as follows:

Liquors:	560	items
Wine:	1,120	items
Beer:	50	items
Foodstuff:	227	items

The facility handles approximately 32.3 million cases of product per year, approximately one-quarter of which are produced in the adjacent plant. The balance comes from other plants. Except for what is shipped out to other (Suntory) plants, the balance of outbound shipments, two-thirds of the total, are destined to wholesalers.

Average daily throughput includes 150 trailers loaded and unloaded per day. Shipped orders range from 500 to 600 per day, totalling approximately 50,000 outbound cases per day.

MATERIAL FLOW AND TECHNOLOGY EMPLOYED

The warehouse covers 8,600 m^2 and has three floors for a total of 25,800 m^2. Figure Suntory.1, an isometric view of the floor plan, indicates that a fair amount of the total space (approximately 15,600 m^2) is dedicated to conventional floor storage for the block stacking of high-volume, palletized unit loads.

The JTEC team only had time to visit the number 3 warehouse described above, and then only the first and third floors. The first floor contained a unit load AS/RS consisting of 8 rows with 23 bays and 3 levels, plus 4 rows with 21 bays and 3 levels, for a total of 900 pallet positions. The AS/RS was dedicated primarily to mixed case pallet loads, which were formed on the 2nd and 3rd floors. The AS/RS actually functions as a storage buffer prior to shipping and serves as an order consolidator at the time of shipping. Individual items within a given mixed case unit load range from one case to one or more pallet tiers per item.

Order consolidation (via the AS/RS) is scheduled and controlled by the site host computer to coordinate with what appears to be a tight (or at least well-planned) schedule of truck arrivals and departures from the loading dock. Fork trucks provide the interface and means of transporting pallet loads from the end of aisle P&D stations to a staging point beside each truck berth.

The truck berths or parking points are actually just that, since there are no raised docks (everything on the first floor is on ground level) and there are no doors. The trucks pull into an expansive, skirted area that is totally roofed. However, the parking places are well marked and each truck is assigned a specific berth, above which is a large, illuminated digital display that identifies the berth and the orders destined to that berth.

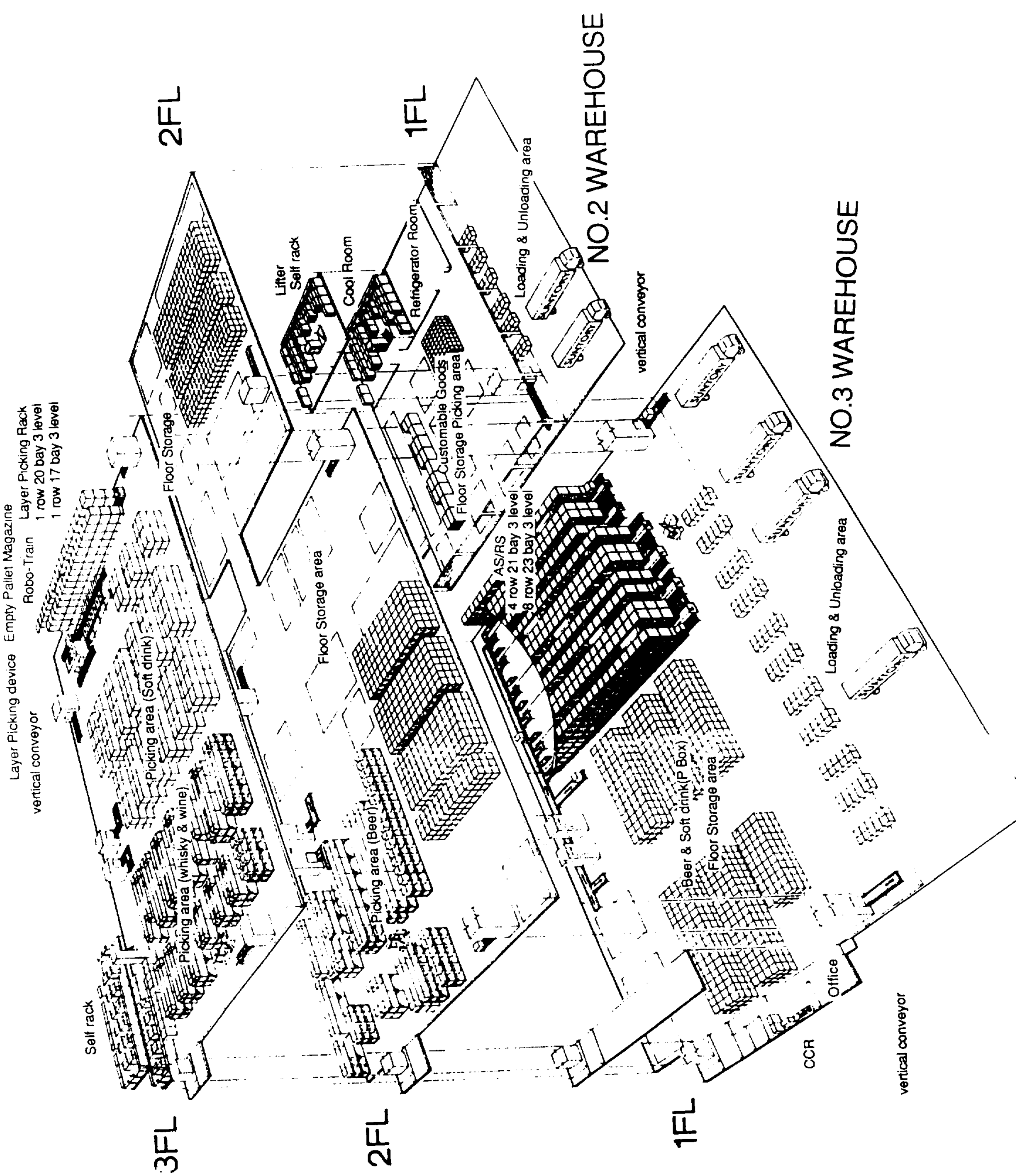


Figure Suntory.1. Kisogawa Plant

Fork truck drivers pick up pallets (from the AS/RS) and deliver them to staging points beside a truck berth in no specific sequence and somewhat in a random manner. Their actions are governed by visually seeing a pallet to be picked up from a P&D station. A computer-controlled, digital display above each end-of-aisle P&D station is also turned on when a pallet is ready (and this too is very visible), with the display showing the truck berth number to which the pallet is to be delivered. It appears to be a very smooth and efficient operation requiring no paperwork (for the fork truck driver) and no requirement for radio communications with the driver. It is a form of pick-to-light.

As mentioned earlier, split-case pallet buildup, and therefore split-case picking, takes place on the third (and probably second floors). Most of the items (medium movers) are stored on pallets in selective rack positions (750 positions throughout the warehouse). The slow-moving items are stored on standard shelving on a mezzanine area of the third floor. Picks occurring on the third floor that are in the one case to less than one pallet tier range are manually picked by operators driving "man-up" order-picking trucks. Picking is aided in this area (the selective rack area) by a pick-to-light system.

This pick-to-light operation, however, takes a fairly unique twist at Suntory. In addition to pick-to-light displays over each pallet picking position, there is also a conventional incandescent lamp or beacon with five colored lenses and five bulbs mounted at the end of each rack aisle at about three meters in height.

The operator receives an order that is color coded (one of five colors for one of up to five operators). The operator then is directed through the order-picking cycle in the following manner. The corresponding colored lens within the end of aisle beacon is turned on by the local computer when the operator first receives his color-coded order. The operator then chooses the aisles by looking for beacons that have been illuminated. After the operator makes the first pick in a given aisle, the lamp extinguishes automatically. It should be noted here that at any one time it is possible for all five colored lenses within a given beacon to be illuminated, which would mean that all five operators have orders requiring picks from that aisle.

Once in an aisle, the operator is directed to a pallet location by looking for the pick-to-light displays that are illuminated. In this case, again, the pick-to-light display has five, small colored bulbs, the correct one(s) of which are illuminated to correspond to the fork truck operator's order color. Attached and hanging down from each display unit are four short chains (e.g., desk lamp chains), each with a colored pull tag. Upon stopping at a lighted display, the operator pulls the appropriate (color-coded) chain, and the (SKU) item number and quantity to pick are shown on the LED display. When the correct item and quantity have been picked, the operator pulls the chain and clears the display register. The operator proceeds down the aisle, and from aisle to aisle in this manner until the order has been picked. Orders are then manually consolidated on a pallet for subsequent automatic transfer to the AS/RS on the first floor.

For orders that include items in quantities of one or more (pallet) tiers, an automatic tier-picking machine is used. Earlier in the order-filling cycle, full or partial pallet loads are stored on conveyors adjacent to the tier picker. Empty pallets are stacked in a single aisle AS/RS, also adjacent to the tier picker.

The tier picker will strip off as many carton tiers as are necessary to complete an order, returning the remaining tiers (and pallet) to reserve storage. The tier picker is a very large, complex-looking piece of machinery. While it operates quite nicely, it appears evident that the cases to be handled must be solid (e.g., beverage cases) because the mechanism gives the cases on the top tier (the one to be picked) a jolt when the picking sequence is initiated. Nevertheless, it does eliminate a lot of manual case handling and stacking.

All unit loads that have been assembled on the upper floors are automatically transported to the AS/RS via pallet elevators and roller conveyors.

Because the entire tour through the facility was fairly brief, at the end of the day, and without the aid of a translator, it was not possible to explore the control system that was coordinating the entire operation. However, it was evident that a great deal of order coordination was required, indicating that a well-designed control system had to be in place.

SUMMARY

From what the JTEC panel learned, all of the material handling equipment in the facility was supplied by Murata, including the tier picker and the pick-to-light installation. The system integration was also performed by Murata, and here again a high level of information integration accompanied the automated equipment. As was also true at the other sites JTEC visited, consultants were not employed in the design of the systems. The supplier was chosen on the basis of competitive design concepts and reputation. Budget pricing was established following selection of the vendor and refinement of the proposed design.

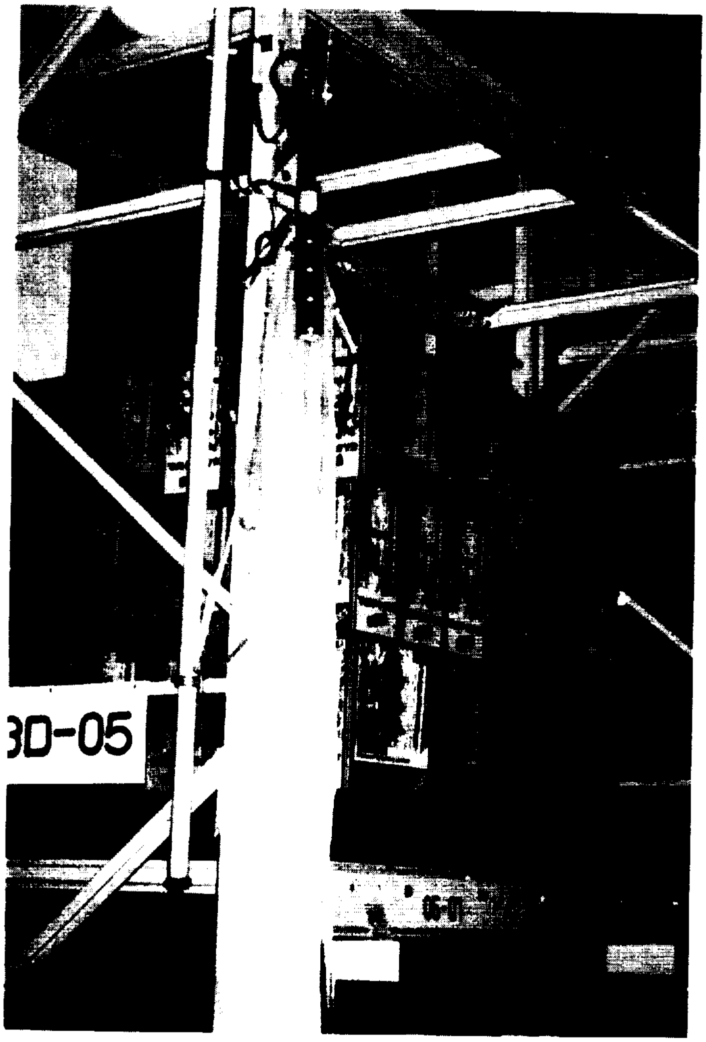


Illustration of split pallet picking to light (Fig. Suntory.2, Left) and associated end of aisle beacon (Fig. Suntory.3, Below) used to guide order pickers at Suntory Kisogawa Distribution Center.

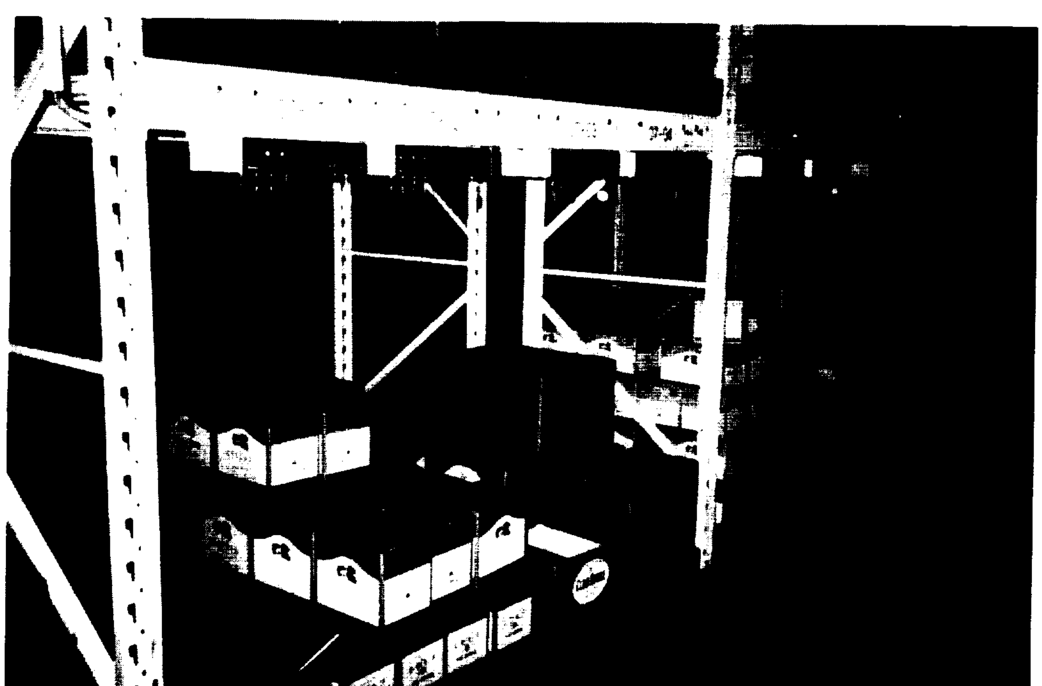
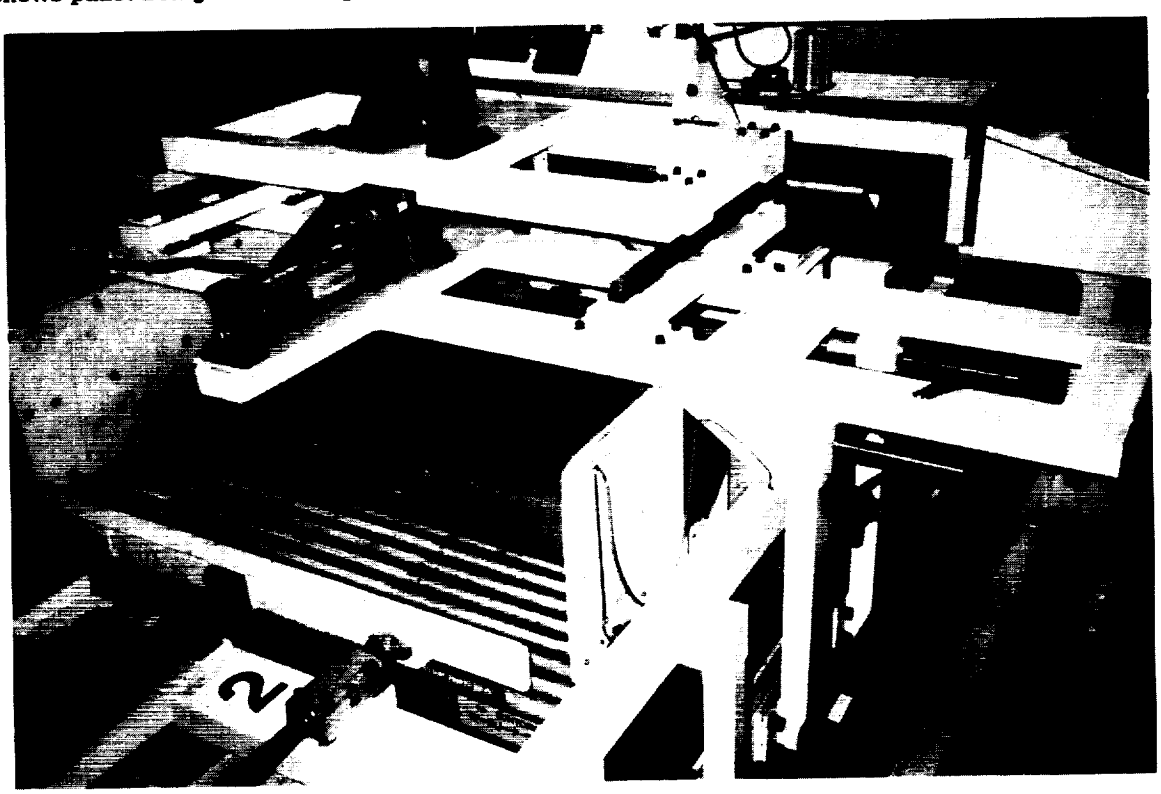


Illustration of tier picking machine at Suntory Kisogawa Distribution Center. Figure Suntory.4 (Above) shows pallet being raised into position and Figure Suntory.5 (Below) shows top tier being picked.



Site:	**Murata Machinery, Ltd.** **Automated Systems Division** **2, Nakajima, Hashizume, Inuyama** **Aichi 484, Japan**
Date:	April 8, 1992
Report Author:	R. E. Ward

ATTENDEES

JTEC:

R. Ward
H. Zollinger
A. Voss
L. Martin-Vega
B. Williams

HOSTS:

Yoshiharu Tanaka	Director and General Mgr., Engineering Grp.
Norihiko Soma	Systems Engineering

BACKGROUND

Murata Machinery, Ltd. is a very large company with four main divisions and numerous subsidiaries. It has operations worldwide (offices and production facilities), including in the United States. The company was started as a textile machinery company in 1935, producing some of the very early Jacquard machines. Today its textile machinery division is one of the leading producers of spinning, weaving and twisting machinery (including the world's first knotless yarn splicer); man-made fiber machinery; and fashion machinery.

In 1961 Murata began production of turret lathes as a forerunner to its present day Machine Tools Division. Today this division is known worldwide for its production of a variety of turning machinery, machining centers, sheet metal machinery and coordinate measurement systems. A well known joint venture in the machine tool industry was Murata Warner & Swasey, Ltd. (1970), which was eventually acquired (100 percent) and merged into the Machine Tools Division (1990), as were some well known German and Swiss machine tool producers.

Murata's current Communications Equipment Division had its start in the early 1970s. Today this division is known for the production of a wide range of facsimile machines and cellular telephones. More recently, Murata has added word processors and computer peripheral equipment, and is steadily becoming a comprehensive office automation (OA) equipment manufacturer.

Murata's fourth division is today known as the Automated Systems Division. It is this division that is known for its wide range of material handling equipment and systems. Today's product lines include automatic guided vehicle systems; automated storage systems (including AS/RS); industrial robots (including palletizers); information handling and control systems; conveyor systems; and a broad line of traditional storage components, including cabinets, shelving and pallet racks. Murata actually began production of the cabinets as early as 1962, and began its Physical Distribution Control Systems Division in the same year (present-day Automated Systems Division). Its first line of AGVs was introduced in 1979.

Although division sales statistics were not available, it is believed that Murata ranks as one of the top three material handling equipment companies in Japan. Murata officials told us that Murata ranks number one in Japan in the export of stacker cranes, and number one in domestic and international markets for stacker cranes of more than 25 meters in height, and for totally integrated systems. It sells and installs systems worldwide, including in the U.S. It established Murata Automated Systems, Inc., in Michigan in 1990.

RESEARCH AND DEVELOPMENT

Our site visit was limited to conference room discussions that were conducted without the aid of a translator. While we were provided with equipment catalogs describing the products and services offered, we were not able to visit their material handling production facilities or to see any of their latest equipment. The team was given a tour of a portion of Murata's machine tool production facilities, where we were able to observe the company's use of numerous automated material handling systems in their plant. This included AS/RS (some well over 15 years old); various AGVs, including tool-changing units; pallet vehicles with a roller deck and tote-carrying units; unit load conveyor segments; automated electrified monorails (AEM serving a mini-load, parts storage AS/RS); and sorting transfer vehicle systems serving two different AS/RS installations.

The sorting transfer vehicle, which operated as an end-of-aisle load transfer machine, was actually very close in appearance to what is known in the U.S. as the SI Car Track System. This technology was originally licensed to the Japanese company IHI by SI Handling system (Easton, Pennsylvania). This system is still produced by IHI and was installed by the company in Japan and Asia. Our hosts explained that the original patent was weak, opening the door for Murata to make engineering changes which, as the company saw it, improved operation of the system. The original change was in the way a drive shaft running the length of the tracks interacted with a reaction wheel on the under side of the car or carrier. More recent developments have been aimed at creating lighter, cleaner systems, making heavy use of aluminum structures.

While the team did not see new developments at the Murata site, it was possible to make observations and to pick up enough of the conversation to know that the company is active in research and development. The company does have a large technical development center, where among other things, it is attempting to perfect computer integrated manufacturing (CIM) and apparently is making use of artificial intelligence as a tool for design and perhaps as a basis for control systems development.

The team also observed a new building being constructed that is to be the home for the company's development and production of automated (handling) systems for use in a clean room product environment. It is already one of the leading suppliers of such systems.

Other developments are also likely to be underway, including new control systems for AGVs. Originally Murata was a licensee of the Swiss AGV company known as Digitron (the U.S. company, Eaton-Kenway, was also an early licensee of Digitron). The Digitron technology was based on in-floor wire guidance. There were indications that Murata is pursuing a ceiling-mounted, optical guidance/navigation system. It has also developed a nonwire, floor-based optical guidance system.

SUMMARY

Murata certainly is a leading material handling equipment supplier in Japan, with a presence also being felt in the U.S. It is therefore a good benchmark from which to compare developments. With the exception of its work in the clean room operating arena, it would be difficult to argue that the company is any more advanced in any one category of equipment than a U.S. supplier. What distinguishes Murata is its immense size as a corporation and its extremely broad line of equipment. There are perhaps only two companies in the U.S. with a line that will come close to Murata's. That is the J. B. Webb Company and the Rapistan-Demag Corporation. The latter has roots with the German giant, Mannesmann-Demag AG.

It is clear that Murata's sheer size and apparent commitment to research and development mean that it is a material handling company that will be around for a long while; it is a company to watch. One sign that it will not stand still is its adoption in 1991 of a new unified brand for all of its automated products, *Muratec*.

Site: **Daifuku Co., Ltd.**
Komaki Plant
1500 Komakihara-Shinden
Komaki-shi, Aichi 485
Japan

Date: April 8, 1992

Report Author: H. Zollinger

ATTENDEES

JTEC:

R. Ward
A. Voss
H. Zollinger
L. Martin-Vega
B. Williams

HOSTS:

Isao Osawa	Executive General Manager, Mechanical and Electronic Products, Operation Headquarters
Haruo Yamada	Manager, Komaki Works, Engineering Department Engineering and Planning Section
Edward Ray	Systems Engineer, Engineering Dept., Komaki Works
Masao Fukui	Chief Engineer, Public Relations and Training Department

BACKGROUND

Daifuku Co., Ltd. is now the second largest material handling company in the world. It has grown at a faster rate than any other medium-sized or large company in the industry. The company's 1991 total sales were $1.05 billion (140 billion yen), up from 1990 sales of $943 million. The Komaki plant, which the JTEC team visited, alone provided 55 percent of the company's total 1990 sales.

Daifuku has two principal groups. The Physical Distribution Group is the largest, followed by Automotive. Both focus on only classic material handling, except car parking. In round numbers, Physical Distribution comprises 75 percent and Automotive makes up 25 percent of the business.

In percent of sales, Physical Distribution is made up of storage systems, 43.5 percent; conveyor systems, 38.8 percent; material handling equipment, 15.2 percent; and other, 2.5 percent.

Daifuku's product line is very broad. Its three businesses at the Komaki and Shiga plants are physical distribution, electronics, and mechanized car parking. The car parking is very new and is not yet a factor in total company sales.

The company's product categories are: automated electrified monorail and plain monorail, conveyor (chain), special purpose machine, automated storage/retrieval systems, automatic guided vehicles, conveying flow systems, clean room factory automation, rotary storage racks, storage and handling equipment, and control equipment, including software.

Daifuku started in 1937 with a 30,000 square foot (3,000 m^2) plant and 150 people. In the seventies, the company licensed some technology from the U.S. In the eighties, Daifuku started developing more of its own designs. With these capabilities in place, in 1987 the company started to expand outside of Japan. Daifuku now has a presence in Thailand, Singapore, Europe, and Canada and has multiple locations in the U.S.

The company philosophy (motto, idea, or slogan) is called "*SK*," which means "thought revolution," and in practice represents a philosophy of meeting customers' unique requirements to the greatest extent possible by building systems that consist of the right combination of standard equipment and software. This affects about 80 percent to 90 percent of the market. Daifuku's high degree of standardization continues to grow, contributing to the company's low manufacturing cost and short delivery and installation time.

Tied to the lower cost of manufacturing is Daifuku's recent approach of using more subassemblies to reduce lead times and reduce the need for stock. One example is the S/R machine control, which once took 50 hours and now takes five hours total for manufacturing the four subassemblies and only two hours to assemble the final product configuration.

Under Daifuku's "physical distribution" market category is storage systems, of which AS/RS comprises a very significant part. Of this, 50 percent consists of S/R machines (stacker cranes). Daifuku produced 1,511 S/R machines in 1990, which was 53 percent of the Japanese market (2,839) and approximately 33 percent of the world market. The U.S. produced under 300, and Europe produced approximately 1,500. Both physically and informationally, these much higher quantities come from the extensive use of single aisle or small systems for work-in-process inventory control.

The other elements of the AS/RS business are racks, machine controls and computer controls. The AS/RS is also supported by horizontal transportation methods.

The other parts of what Daifuku refers to as the physical distribution portion of its business include systems using conveyors, sortation, AGVs, AEMs, rotary racks, and clean room system equipment.

In keeping with its motto, *SK*, is the company's extensive use of pre-engineered systems or combinations of standard products. The ratio of pre-engineered to "one-shot" (custom applications) systems is approximately 80 percent to 20 percent. This is relative to AS/RS systems. The 80 percent figure is higher than any in the U.S., and somewhat higher than most standard suppliers in Europe.

Daifuku's definition of "pre-engineered" includes all of the applications that fall within the realm of the standard and semi-standard module product line. Standard is further defined where all facets of equipment design are completed without requiring an engineer's review. These are based entirely on standard drawings, the only variation of which is determined by the critical load and installation space dimensions. These systems are handled by the company's "AS/RS planner" computer program.

Semi-standard includes products that are made up of standard modules arranged in a nonstandard way, or standard modules to which minor changes must be made. An example would be a standard double-deep shuttle on a standard S/R machine not normally designed for double-deep applications. An engineer would have to check the stress involved to approve the application.

"One-shot" or custom applications include development of a new application to specific products, as well as major modifications to standard products. An example is the redesign of the upper and lower frame of an S/R machine to handle extremely long loads. Relative to the company's other material handling systems, including the larger integrated systems, the ratio is more like 60 percent standard to 40 percent custom.

The second major business at Komaki is electronics. An extremely important part of Daifuku's strategy and success, electronics makes the company self-sufficient and dynamically responsive.

Just like Daifuku's mechanical equipment modules, the controls are based on distributed control. This is dynamically shown in the company's conveyor controls.

Daifuku manufactures a lot of its own controls. Because of the company's broad offering, Daifuku does not have to develop or build everything. For example, the company's partially-owned U.S. subsidiary, Eskay in Utah, works with a software and controls company that has been retained by Daifuku to develop more standard software for its AS/RS systems. The company has learned to use outside suppliers to add to its product line. To this extent, Daifuku does OEM sourcing of some of the products it advertises or sells with its own control components.

Research and development is very important to Daifuku. Of its total sales, the company spends 4.5 percent on research and development. The company obtains its market information directly from personal contacts. The company does not send out questionnaires for user opinions.

Daifuku's technical staff is: electronics, 15 percent; software, 50 percent; and machine design, 35 percent of the total. 360 technical professionals comprise about 40 percent of the 900 people at Komaki. At the Shiga plant there are 300 technical staff members, and at Osaka there are 350 to 400.

At the time of the JTEC visit, our hosts Mr. Osawa had been searching for an acronym for distribution automation. Daifuku Komaki now uses the acronym "FA&DA" for its factory automation and distribution automation market thrusts. This may have been in part a result of talking with the panel.

Each of the product categories are mentioned in the section on technology. However, note that:

1. Conveyors are important to Daifuku, but since the company has so many other horizontal transportation products, it does not rely on this technology. Company employees must make the best selection.

2. Daifuku is second or third in sales in Japan of automatic guided vehicles. The company sells two to three times as many sorting transfer vehicles, which are nearly a proprietary product. IHI and Murata both have car-on-track products that are in competition, to some extent.

3. Clean room factory automation is focused in the electronics industry, but with the need for quality in other industries, this is expanding.

4. Daifuku's storage and handling equipment product line features good innovation implemented in a simple way. The company's new Shiga plant is very modern; unfortunately, the panel did not have time to visit it.

The Shiga plant has a new automated rack manufacturing line. The new rack design uses "pop" rivets instead of welds. The plant has a fully automatic plastic pallet production line that produces palletainers, rolltainers, and shelving.

Daifuku plans to move more of its production to this plant; some of the conveyor production may be there already. The new plant occupies only one-fifth of the total property. The Komaki plant is landlocked.

TECHNOLOGY EMPLOYED

In the mechanical and controls areas, all of the modular products are designed to be applied with as little engineering as possible. The JTEC panel witnessed the mechanical capability, but without more time, did not see a demonstration of the control modularity. However, the information provided by Eskay on computer controls illustrates some of this computer control modularity at the upper end.

A few observations are provided below concerning the technology employed in each of the main product and system categories. A capabilities brochure was provided to each JTEC team member.

Automated Electrified Monorail and Plain Monorail

Most of the monorail products are motor driven. Reference literature showed an LIM (linear motor)-driven small carriers product.

The products range from 110 pounds (50 kg) to 4000 pounds (1800 kg) capacity. There are both ceiling and floor (inverted) supported systems; the capability is similar to that of other similar products in the U.S., except for the smallest units, which are miniaturized and operate at the upper end of today's speed ranges.

Conveyor

Conveyor products, by definition, include power and free products, straight power products, and a broad line of package conveyors. No new technology was discussed. However, other related Daifuku products are discussed below under Conveyor Flow Systems.

Special Purpose Machinery

Daifuku builds automatic engine-mounting machines, engine test stands, locate pin step change machines, special-looking AGVs, and multi-level high-speed "servers" (rail-mounted shuttle cars at each level of a rack) in this category of products.

Automated Storage/Retrieval Systems

Daifuku has made the greatest progress in this area. The company's machines are well designed and extremely reliable. Its main applications are in distribution and manufacturing. The company claims that the new unit load small system will do 180 single cycles per hour, which is a 20-second cycle.

The panel also saw a mini-load system that reportedly does 133 dual cycles per hour (266 loads handled), with a 27-second cycle. The dual cycle rate is hard to believe: The fastest known is 120 duals with drives off the mini to get the weight down and independent of low friction and skidding wheels. Although it was not apparent, the system must have an all-wheel drive.

The micro machines are starting to be used in an office environment for supplies and documents. They appear to be 6 to 8 feet (2 to 2.5 meters) high.

The panel saw the new 9X model AS/RS in the test and demonstration hall. It has an on-line "help" idea, learning functions to teach the system characteristics (part of a 1988 model), and using the bottom markers for gross position. In addition, each column is read to correct for any leaning racks. The diagnostics are impressive and maintenance is very operator-friendly.

Daifuku builds stand-alone systems and rack-supported buildings.

Automatic Guided Vehicles

Daifuku's AGV technology is changing as the company tries to use surface-mounted ceramic responders. It has been using flexible (PVC-covered) magnetic strips for the guidepath instead of a wire in the floor. Daifuku tapered the edges to get it to stay on the floor with cross traffic.

Sorting transfer vehicles are included in this Daifuku product group. Daifuku has mainly birail systems for light and heavy loads, and monorail technology for light and small loads. These were all reported as motor-driven. We didn't see any LIM operating units.

The very effective loop systems are used in AS/RS front ends and in manufacturing. The reciprocating type are the same vehicles, but for lower throughput and space restrictions.

The company's STV technology outperforms its AGVs for compact AS/RS front ends and compact plant manufacturing. Daifuku uses AGVs for long-range systems. The company also uses combination systems.

Conveyor Flow Systems

"Conveyor flow systems" are known in the United States and Europe as package or tote conveyors. Daifuku uses extruded aluminum side channels for flexibility and a clean appearance. Daifuku conveyor systems are quiet.

One of the unique components and product designs is the accumulation conveyor. Every supporting roller is individually driven by its own friction wheel. Each friction wheel is mounted in its own plastic frame, which mounts under the conveyor rollers. Each wheel is driven by a common chain and is lifted by air to make contact and drive. Accumulation zones are set by photos that control the air in the area. Figure Daifuku.8 shows several sizes of the plastic units and a diagram on the wall.

Daifuku builds at least four types of sorters. The ski and surfing sorters are the newest and are in the test and demonstration hall. The ski sorter is a cross belt sorter used for small parcels and plastic gags. The surfing sorter is a shoe sorter or positive sorter. The other two are the pan sorter (mini-tilt tray) and the popskew sorter, which is a two-directional pop-up roller sorter.

Daifuku has 112 patents in the conveyor field alone.

Clean Room Factory Automation

This line consists of AGVs, clean monorails, and robot stockers.

Rotary Storage Racks

This line contains both horizontal and vertical-type carousels.

Storage and Handling Equipment

These products, which include racks, plastics pallet, pallet rack, shelving, level carts, palletainers, and rolltainers, provide general support to the system.

Control Equipment, Including Software

Daifuku uses simulation software, AUTO-MODE, for its projects. AUTO-MODE is a registered trademark of ASI.

Only the shuttles mounted on the STV will operate in two directions. The loop is unidirectional, but the reciprocating STVs are bidirectional.

The C-Box (individual controls per conveyor) Network is built in. The network is a custom Daifuku product, and is not compatible with other LANs.

The panel saw one ARC (AS/RS Real-Time Controller). There are three models of ARC. Above this in the control hierarchy is the RTS (Real-Time System). Five models of RTS are available in the United States; more models will be developed. MOS goes with ARC for data or tracking using windows. The centralized material handling computer is above the RTS in the control hierarchy.

The company's third main business is mechanized parking systems. Daifuku builds elevator-type systems and contracts for its service (maintenance).

ADDITIONAL OBSERVATIONS

Daifuku's picking cart with "smart card" for information transfer and with infra-red communication to the cart as it enters an aisle is new. It can pick up to twelve orders simultaneously, whereas Pola's maximum was eight. In the past, the picking cart only picked one side of the aisle; now it can pick both sides.

Daifuku has done a very small amount of work with "inertia," or off-guidepath, guidance. The company knows of others who have done some. The company does not use as many AGV applications, because the throughput is less than its STV. Where Daifuku has done systems with no guidepath, it has used ultrasonics and lasers.

Material handling courses are taught at the universities, but there are no majors in the subject. The universities do very little development in the field of material handling. However, there is some cooperative development in electronics with university personnel, like the new guidepath, for example.

SUMMARY

Daifuku has the broadest offering of any Japanese material handling company. The company produces a broader line of non-crane material handling equipment than anyone. Daifuku does not participate in the crane field. The company rivals Mannesmann-Demag AG of Germany, the largest material handling company in the world.

In its manufacturing of mechanical components and assemblies, Daifuku is very clean and its workmanship is excellent. The assembly lines help in reducing cost. The products are designed for manufacture and ease of assembly. They are tested and run before they leave the factory. The test loop for STVs, for example, has four concentric rail loops with one common rail with collectors. These cover the product range, but in a small space.

Except for the STVs, there is no single technology at Daifuku that is strikingly ahead of that in the U.S. The execution and installation of the products is very good and remarkable because there are so many.

QUESTIONS ASKED BY PANEL

Research & Development

Q. To what extent is standardization in the area of software controls and/or bar-coding being utilized to facilitate automated material handling applications, and what are those standards?

A. *Software controls: As far as Daifuku knows, material handling makers are all doing their own "standardization." There is no intentional cross-company standardization. Daifuku has several standard software/hardware packages for both equipment and inventory control. These packages are made of modules, so that systems can be outfitted with as little customization as possible. Bar-coding standards exist. Daifuku uses code 39, 2 out of 5, and others as required.*

Q. To what extent are external factors influencing either product research and development or the application of material handling technologies? Examples might include (a) local and/or national safety codes dealing either with equipment design or equipment application, and (b) trends in ergonomics and human factors engineering.

A. *Labor force: The mean worker age is increasing; the overall shortage has led to an increased need for material handling equipment, but it must be easy to operate. Product liability: What is happening in the U.S. is also beginning to occur in Japan. Safety is a major priority. Land prices: Prices remain high and many companies are landlocked. Vertical space must be utilized. Environment: This is a current social theme. All development is to take the environment into consideration.*

Q. Are there any specific government programs that act as incentives to either product research and development or the purchase and installation of modern, automated material handling equipment and systems? Examples might include investment tax credits or university/industry cooperative research and development programs.

A. *Daifuku does not know of any at present. The company is not currently involved in such a program.*

Q. What segments of the material handling industry are receiving the greatest attention in research and development, and what facets of specific products (e.g., speed, accuracy, noise, maintainability) are receiving the greatest attention?

A. *Daifuku believes accuracy and noise problems have long been solved. They consider speed is an important issue. With respect to Daifuku's initiative in the parking system market, maintainability is of utmost importance, since parking system operators do not have heavy equipment maintenance ability. While it may not be considered traditional material handling, one of the most emphasized segments at Daifuku currently is the parking system.*

Q. How are priorities for material handling research and development established? What are the means for the material handling user community members to express their needs to material handling suppliers?

A. *Integrated with Daifuku's sales groups are market research departments, largely dedicated to researching customer needs. Visits to customer facilities and brain-storming meetings are emphasized. Out of these activities come R&D topics. The company does not use questionnaires.*

Q. Is there a general trend in the Japanese material handling industry toward pre-engineered, modular systems?

A. *Daifuku has adopted this method extensively, both for hardware and software.*

Q. What are the latest developments in AGV guidance technologies? What portion of the AGV installations have off-wire guidance capability?

A. *Daifuku's latest AGV guidance method consists of a plastic-covered magnet surface mount guidepath with ceramic station markers. The company has no recent installations that use wire guidance. All are magnet-based.*

Applications/Trends

Q. Of the material handling products currently being manufactured and installed in Japan, which are being produced under license from either U.S. or European manufacturers?

A. *Daifuku manufactures overhead chain conveyor and wire mesh containers (palletainer) under license from U.S. companies. The company also has a license with a U.S. company for control equipment OS.*

Q. Are there any aggregate statistics compiled that quantify the trends in installations involving AS/RS, AGVs, or automated monorails? Trends include not only the total number of installations but also characterize installation according to their use (e.g., manufacturing, warehousing, distribution, etc.) and the size of the systems (e.g., number of storage locations, number of aisles, number of vehicles, etc.)? In general, what are the trends?

A. *Yes, statistics are taken.*

Q. To what extent are independent material handling consultants used in the planning and design of new material handling installations?

A. *Daifuku does not use material handling consultants.*

Q. What role, if any, do distributors play in the material handling industry in Japan?

A. *Daifuku uses distributors as inquiry pipelines and as very low-level advisors (to the customer). They are not used for engineering or service, and so forth.*

Q. How are automated material handling systems employed outside of factories and warehouses (e.g., in hospitals, shopping malls, and private residences)? Can we visit a recent installation?

A. *Hospitals and libraries use the uniway system. They have just begun marketing the pin stocker for office use. The regular material handling equipment is also used in hotels (conference center), and in restaurants for dish storage and delivery to the kitchen.*

Q. How large is the market for mobile pallet rack and shelving in Japan?

A. *Daifuku compiled statistics for 1991:*
Pallet class: $53-60 mil/year (7-8 billion yen/year)
Mini-load class: $114-136 mil/year (15-18 billion yen/year)

Nihon Butsuryu Kanri Kyogikai member survey for 1990: (Multiplying the following statistics by 1.5 should give approximate numbers for the entire Japanese market.)
Powered rack: $86 mil/year (11.4 billion yen/year)
Manual: $38 mil/year (5 billion yen/year)

Q. What specific steps are taken by the supplier and user to reduce the start-up time for automated material handling systems?

A. *Use of pre-engineered systems is Daifuku's most important contribution to this area. The company also has programs for built-in commissioning and built-in testing that facilitate this. Estimation has been automated (AS/RS planner). Also, components are being premanufactured, (i.e., manufactured before an order is received), for stock as subassemblies.*

Q. Rank these factors in justifying the installation of an automated material handling system for an order-picking warehouse: return on investment, improved response time, improved accuracy, improved space utilization, reduced labor requirements, and improved human factors and safety.

A. *1. improved accuracy; 2. improved response time; 3. return on investment; 4. reduced labor requirements; 5. improved human factors and safety; 6. improved space utilization*

Q. How extensively have the "just-in-time" and *Kaizen* philosophies been implemented in warehousing, distribution, and logistics?

A. *Daifuku's customers would be the best source for this response, but Daifuku feels that JIT and recent changes in what JIT is have caused extensive changes in warehousing and distribution. Previously JIT was the maker's responsibility, which forced him to automate warehousing. Now there are JIT middlemen who use automated warehousing and distribution extensively.*

Q. Do most large Japanese companies have departments for material handling, industrial, methods, and distribution engineering?

A. *Daifuku believes that most large Japanese companies have departments for all of the listed functions. The exception is with some of the retail and wholesale companies.*

Q. How extensively are time standards used in warehousing and material handling activities? How are they developed (e.g., stopwatch, predetermined, work sampling)?

A. *Daifuku deferred to the users on our tour for a response.*

State of the Art

Q. What is the state of the art in: automatic palletizing of mixed case sizes, automated packing and packaging, automated trailer loading/unloading, robotic order-picking for small items, and automated case-picking and flow rack replenishment?

A. *Daifuku's new robot palletizer can handle mixed case sizes under certain conditions. SPC (overhead monorail) is used to automate flow rack replenishment. Other equipment is currently purchased or one-shot engineered as needed.*

Q. Is random container storage being utilized in mini-load AS/RS?

A. *The majority of mini-load applications are handled without using fixed locations for tray or part assignments.*

Q. Are there any robotic case-picking operations in Japan? If not, is robotic case-picking thought of as a near-term possibility?

A. *There are not too many, but Daifuku expects interest and development to grow quickly over the coming years.*

Q. What are the latest developments in light-aided and computer-aided order-picking in Japan?

A. *Daifuku's latest technology is the pick cart that operates with a smart card.*

Q. What are the latest developments in automated sortation for small items in Japan?

A. *Daifuku's latest technology is the ski sorter, which is a cross-belt sorter with individual belt conveyors on linked carriers in a loop.*

Q. How is artificial intelligence being used in the design, operation, control, and maintenance of material handling systems?

A. *The only place in which Daifuku appears to be using AI is in automated proposal tools such as the "AS/RS planner."*

Q. What percentage of inter-company transactions are accomplished via electronic data interchange?

A. *Daifuku does not believe that EDI is being used extensively in Japan.*

Q. To what extent are radio frequency, infrared, and other signal communications medium being employed to remotely control integrated system installations?

A. *Daifuku uses infrared for its stacker crane communications and for batch file commands to its AGVs. The company also uses infrared OBZ communications between STVs. For communications to the STVs, Daifuku uses RF.*

Q. To what extent is distributed (versus centralized) processing being utilized in the control of integrated system installations?

A. *Daifuku uses distributed processing extensively. It allows the company's pre-engineered equipment and controls concepts to work.*

Q. To what extent do Japanese producers of material handling equipment use modern, automated production methods in their factories? For example, do storage rack manufacturers employ robotic welding in the fabrication of rack components?

A. *On our tour of the Komaki factory, automation in production was being used. Also, it was reported that there was an entirely automated (no humans) plastic pallet line at the Shiga factory.*

Education

Q. Are courses in material handling systems and/or machine design taught in undergraduate and/or graduate programs in industrial and/or mechanical engineering?

A. *Yes.* [The panel later learned that the hosts were referring here to courses, but not to degree programs.]

Q. Is physical distribution and/or logistics taught in business or engineering schools?

A. *Again, courses are taught, but degrees are not offered. It is still normal for people from different fields to learn material handling on the job at a material handling manufacturer.*

Q. Is there a formal professional certification program in material handling and/or logistics? If so, who sponsors it and what role do universities and/or professional societies play?

A. *Daifuku does not know of any.*

Standards/Standardization

Q. Does the Japanese material handling industry engage in any cooperative or jointly-sponsored product testing? If so, what segments of the industry (e.g., storage rack manufacturers, unit load container manufacturers, or equipment specific manufacturers such as industrial (fork) trucks, AS/RS, AGVs, monorails, conveyors, etc.) work in this manner?

A. *None that the company knows of.*

Q. Does the Japanese material handling industry engage in the development or promulgation of any jointly-sponsored industry standards on design and/or safety? If so, what type of process is used to accomplish this and what specific standards exist?

A. *Yes. One is the Sangyo Kikai Kogyokai and another is the Nihon Crane Kyokai.*

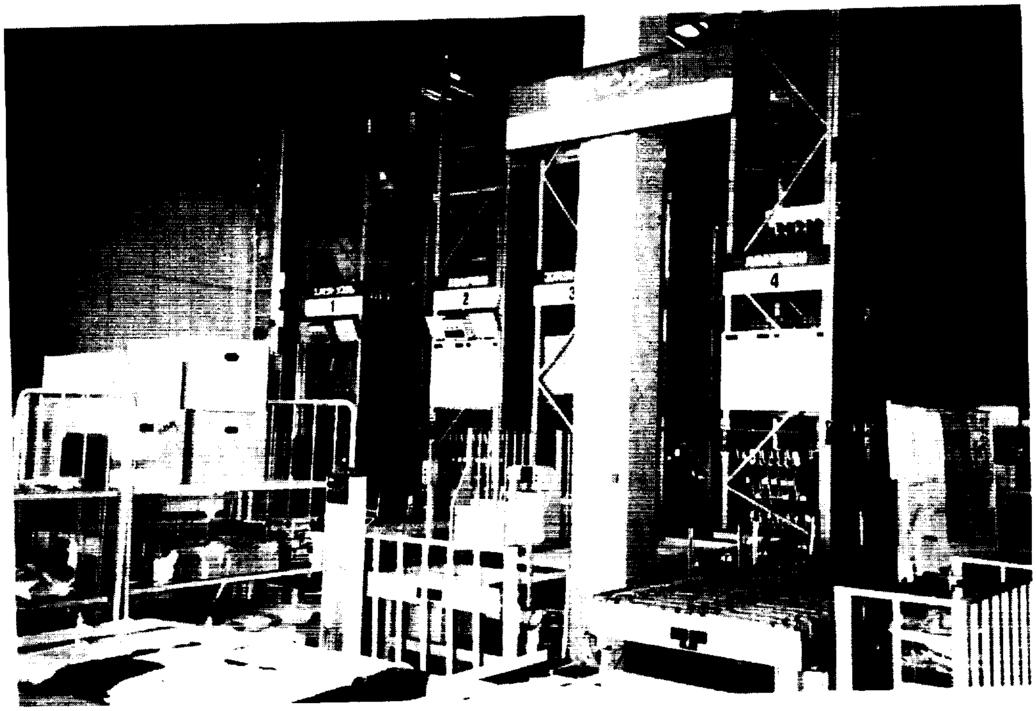


Figure Daifuku.1. Two of the three- or four-aisle, unit load AS/RSs used as Daifuku's distribution center. This four-pallet high system with the double-masted S/R machine is typical throughout Japan. It is five years old. New manufacturing methods have reduced the stock and delivery time.

Figure Daifuku.2. Reciprocating-type pallet STV (Sorting Transfer Vehicle) with shipping accumulation conveyors on the left and P&D stations on the right. Note the KBK overhead crane equipment.

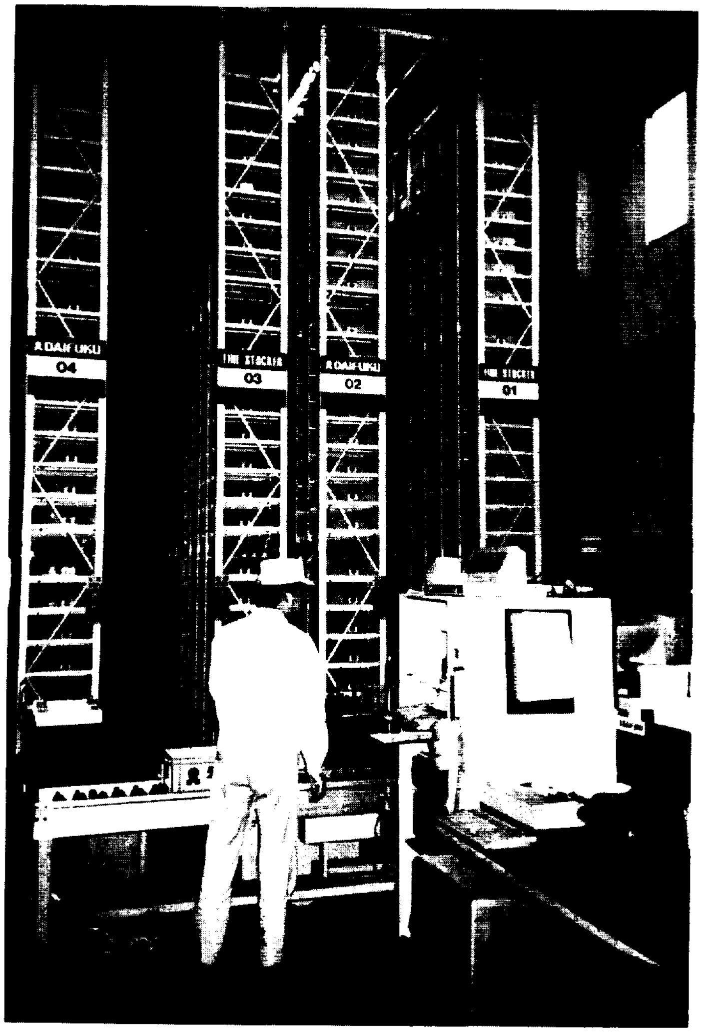


Figure Daifuku.3. (Left) Two-aisle mini-load system in Daifuku's distribution center, with a PC in the front for handling inventory.

Figure Daifuku.4. (Below) The new modern version of the company's unit load AS/RS in a single aisle. The storage machine and end-of-aisle controller have many operator-friendly features.

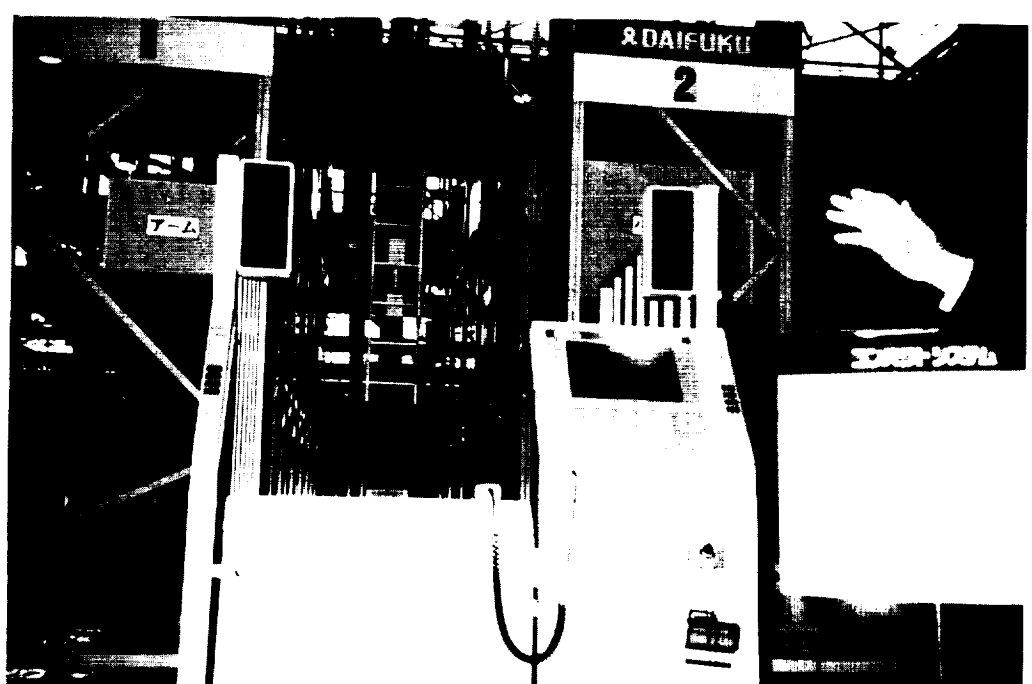


Figure Daifuku.5. The JTEC panel's tour guide using an instruction book with bar codes to provide operator commands to the storage/retrieval machine. This is also used for diagnostics. Lower right corner shows the 1,000 kilogram capacity, 63 meters/minute horizontal speed.

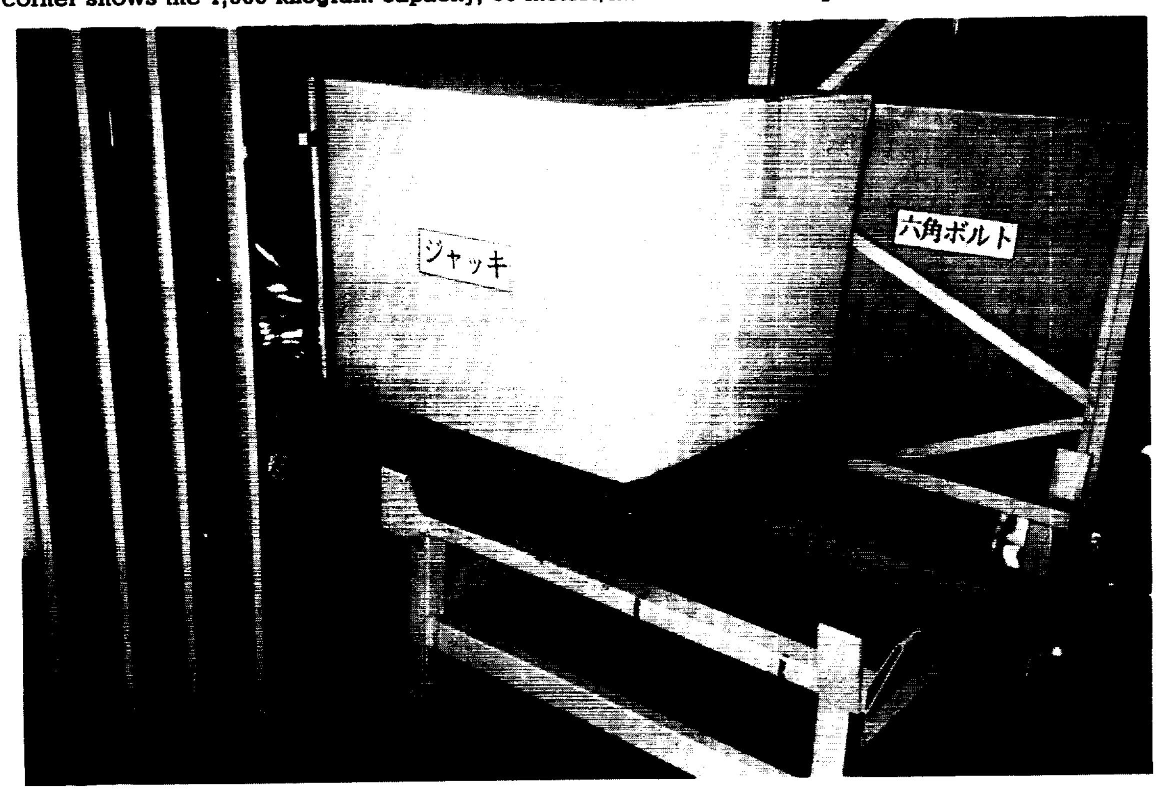


Figure Daifuku.6. The new unit load S/R machine picking up a pallet from a static, fork truck-type, P&D station.

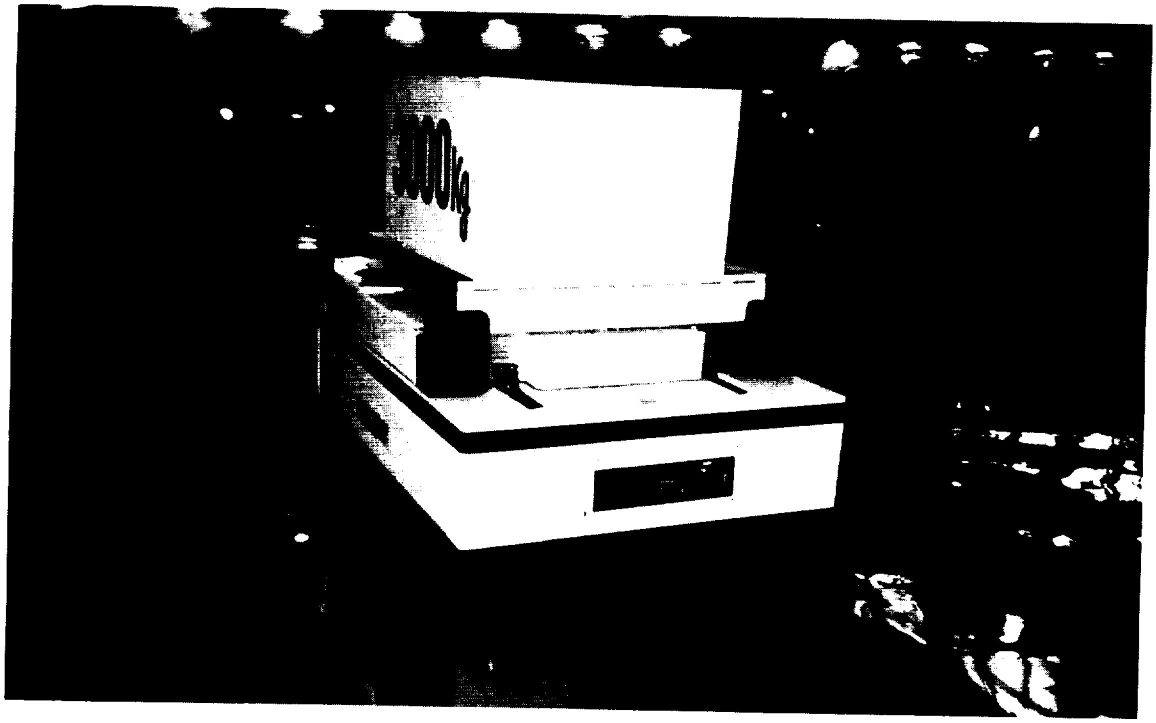


Figure Daifuku.7. The Daifuku demonstration hall containing the new AS/RS, the pictured AGV system, the conveyor in the background, and three other types of material handling equipment.

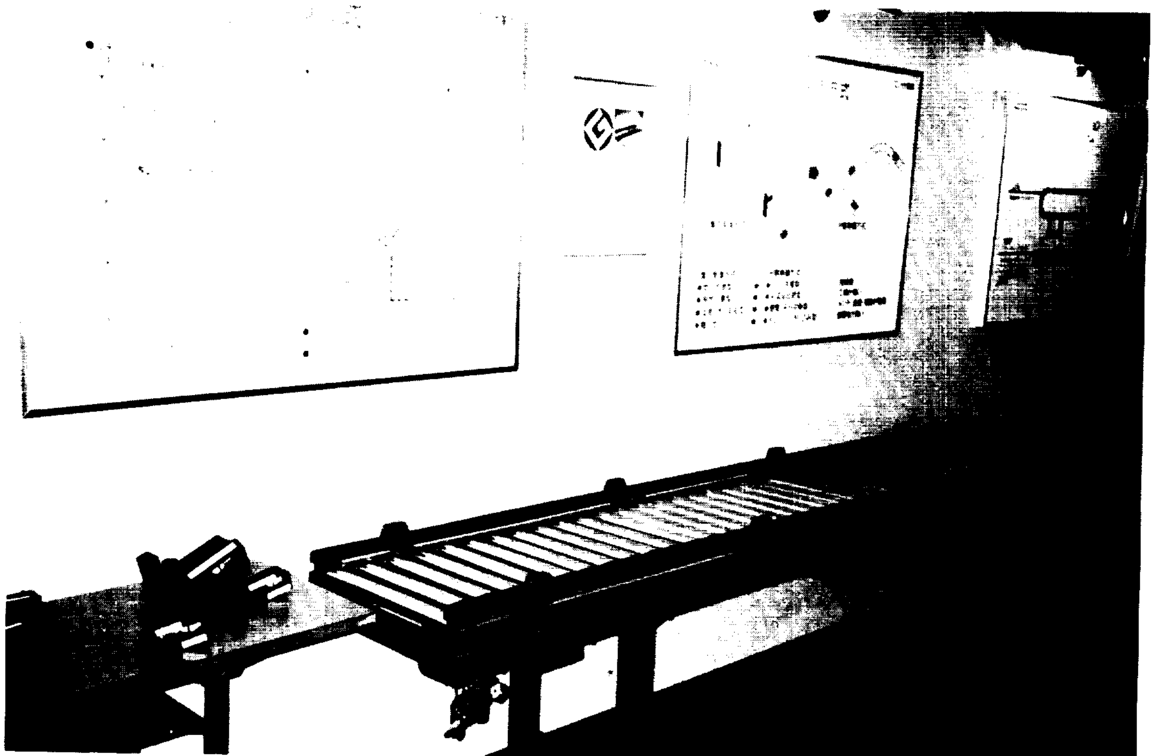


Figure Daifuku.8. The Daifuku accumulation conveyor with individual, friction-driven roller, using molded plastic parts shown in the diagram in the lower left corner of the photo. The accumulation is photoelectrically controlled, with air operating the individual friction drive wheel's position.

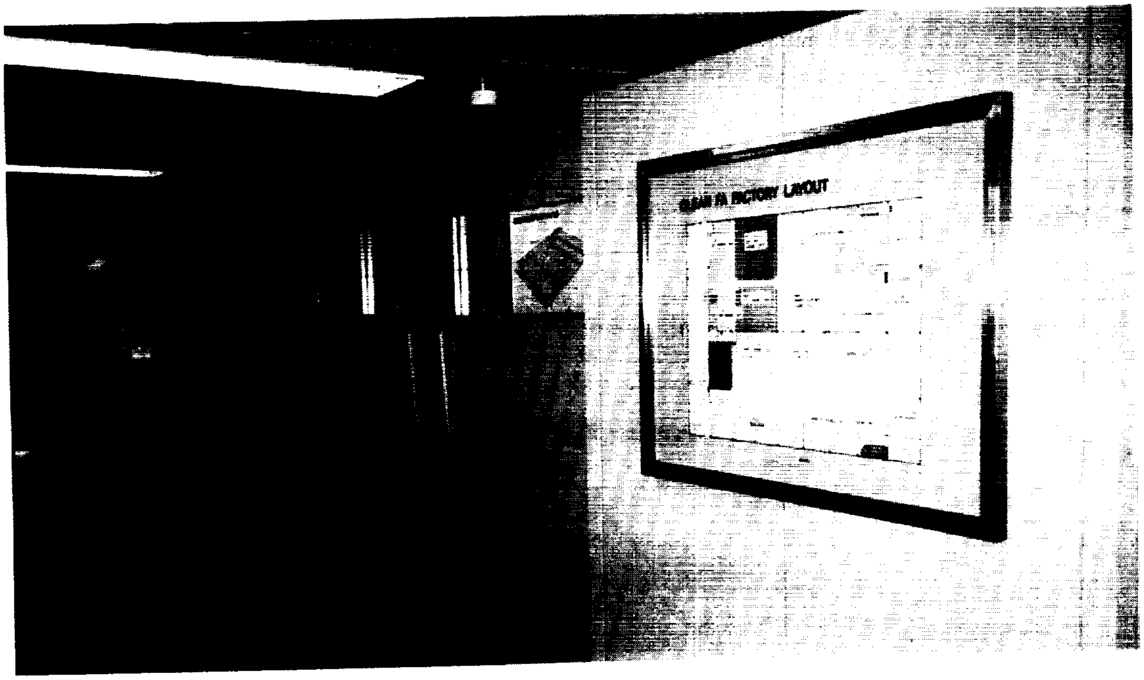


Figure Daifuku.9 The illustration on the wall is a clean FA factory layout; some equipment is shown in pictures to the left.

Figure Daifuku.10. Showing the mini-load shuttle mechanism, which handles mini-load trays by using a hook to grab the tray and pull it on board or push it into an opening. The system is located in their office sorting local office supplies.

Site: **ORIX Rentec Corporation**
1161 Kanamori
Machida-shi
Tokyo 194, Japan

Date Visited: April 7, 1992

Report Author: H. Zollinger

ATTENDEES

JTEC:

R. Ward
A. Voss
H. Zollinger
L. Martin-Vega
B. Williams

HOSTS:

Yoshimi Mizoue	General Manager, Tokyo Distribution Center
Y. Hasegawa	Productivity, Section Chief
Edward Ray	Interpretation and Technical Support, Engineering Department, Daifuku Co., Ltd.

BACKGROUND

The ORIX Rentec Corporation is the leading renter in Japan of scientific instruments and computers. Its business grew to $320,000,000 in 1991. It is recognized as the most knowledgeable in the use of the equipment and the calibration of the instruments. This recognition brings in a significant portion of its business as sole source.

The corporation was founded as a result of studies of U.S.I.R. in California in 1973. The founders likewise visited other companies in the U.S. and Japan. After these visits, a business plan was developed and the company began operating some time before 1980. From this beginning, the company grew at 150 percent per year for the first seven years and has continued at 20 percent since. ORIX expects this growth to continue for at least five more years. The company now has a 60 percent market share.

Currently, ORIX has 30 offices in Japan and ships daily all over the country. The two main inventory locations are in Tokyo and Osaka. The company is completing a new automated facility in Osaka and will move in soon. The Tokyo Distribution Center handles 70 percent of the company's rentals and Osaka handles 30 percent. The company expects this to change to 60 percent/40 percent when the new facility begins operating.

On an average day ORIX receives five truckloads of rental returns, consisting of approximately 1,000 units total. Each unit returned will contain all the necessary accessories, hardware and software needed to perform the function intended. Likewise, the average day in shipments is 1,200 units, complete with accessories. ORIX has its own fleet of trucks for delivery and pickup. This is true except for air shipments, where the company uses common carriers or air freight companies.

The range of uses of instruments are: (1) chemical analysis for environmental testing; (2) high frequency satellite broadcasting calibration for simultaneous testing; (3) computers for counting (i.e., vocational schools may require computers for only one month) or a company project; and (4) work stations for development purposes. Also, ORIX customizes the hardware for special applications.

The company's staff of highly-trained scientific personnel maintains its procedures for accuracy and calibration to nearly equal the Japanese equivalent to our Bureau of Standards' highest ratings, which are only used to check the standards. This level of quality and calibration is carried into each department, well above that required. This in-house capability is recognized by the scientific community and brings the company sole source rentals. ORIX also provides a paid service to calibrate other companies' instruments.

With today's need to test for environmental compliance, and with companies holding down capital spending by not having their own instruments, ORIX has a prosperous business.

To support this business, the company has invested $38.5 million (¥5 billion) in building, equipment and software. Of this, $12.3 million is in the material handling system, including the distribution center computer but not the company's host computer.

MATERIAL FLOW AND TECHNOLOGY EMPLOYED

The flow can be nicely handled by starting with a returned instrument and covering the technology as we go.

The facility is a five-story building located on a 88,000 square foot (8,800 m^2) site (see Fig. Orix.1). The first floor has the receiving and shipping operation; the second has the packing material storage; the third has OA (office automation) inspection and test; the fourth is for high frequency testing, such as work stations (Sun, IBM, and others); and the fifth has the cafeteria and open warehouse. The three largest AS/RS systems are in the back.

There are approximately ten receiving dock spaces and ten shipping spaces. The units are received in the protection of their special boxes, unpacked, put on special slabs, and coded to one of five destinations by the position of a retro-reflective marker on the slab.

These destinations are for the third or fourth floor, either office automation or high frequency categories. The inspection departments check to see that every function shipped is returned and that the number of pieces coming back are complete. Each unit is checked and tested. The departments have automatic testing equipment for IBM, MAC and NEC computers.

Conveyors are used to facilitate easy movement through inspection and test. Because of the large amount of space required on the conveyor, ORIX has chosen horizontal gravity for cost considerations. It is all clean line, extruded aluminum side channel conveyor manufactured by Daifuku. This type of conveyor is often used in flexible manufacturing because it is easily rearrangeable and offers a pleasant environment. The extrusion permits easy positioning of the limit switches and photo sensors.

After inspection and test, the instruments are routed to storage in one of the three main AS/RS systems. The special slabs are two sizes of footprints. This makes the first split. The smaller size is stored in the new eight-aisle mini-load system (Fig. Orix.5), and the larger in the new seven-aisle system. It was not clear what was stored in the older, five-year-old, eight-aisle system. The older system has only one shuttling STV, so one could conclude that the slow movers are stored there. Together, all three systems provide 83,000 openings. The new smaller slab system has three heights, 140 mm, 300 mm, and 500 mm (approximately 6 in, 12 in, and 20 in), and the larger slab system has two heights, 300 mm and 500 mm (approximately 12 in and 20 in). The building height is the same, but the configuration provides fifteen levels of small slab units and ten of the large.

The new S/R machines provide a storage and retrieval capacity in the upper industry throughput range. Their seven-second fork (shuttle) cycle is fast, but not the fastest in the industry. Also, the travel speed of 400 fpm (120 m/m) and hoisting speed of 200 fpm (60 m/m) are fast, but not the fastest in the industry. They were the upper end of fast when they were installed two years previous to the JTEC visit.

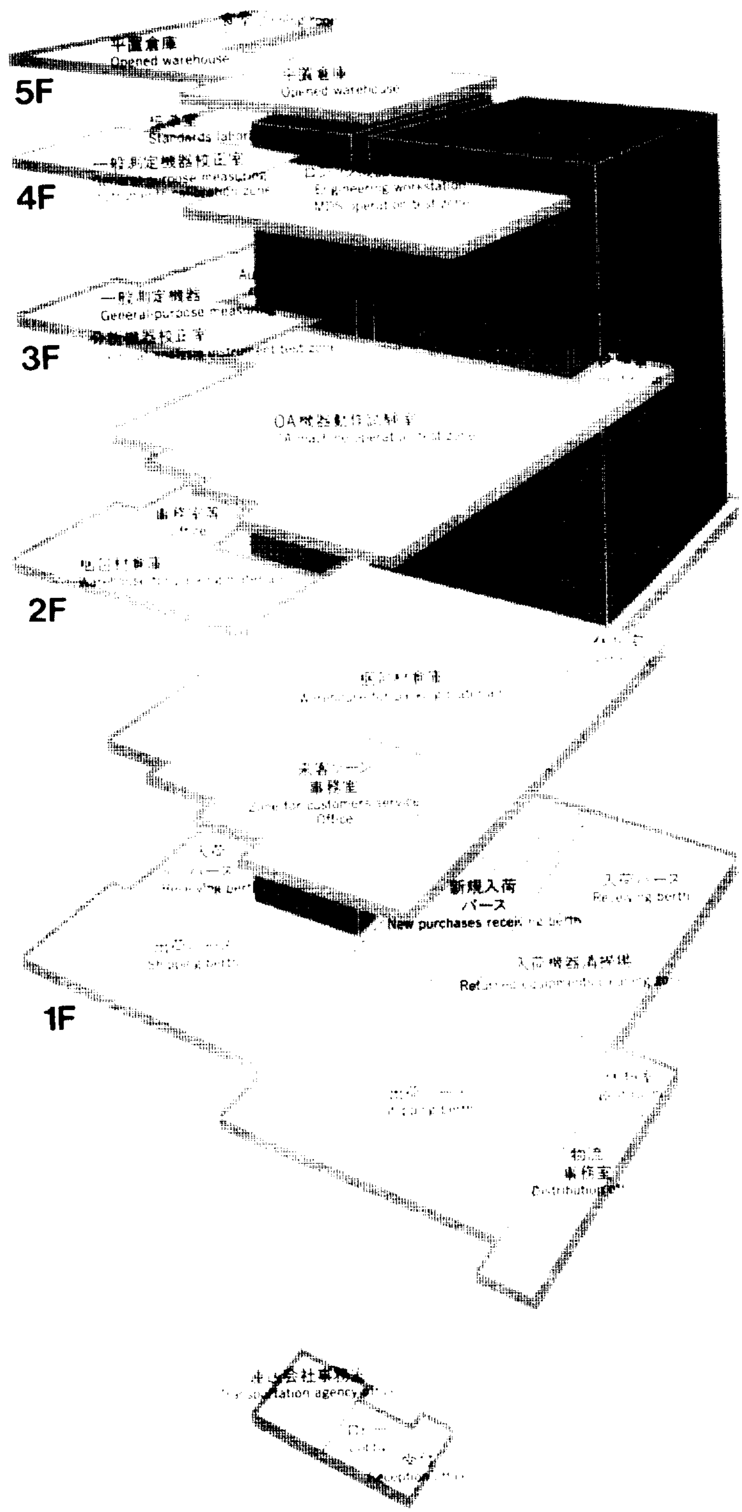


Figure Orix.1. Floor information - Orix Technical Center

The STV (Sorting Transfer Vehicle) technology loop arrangement is somewhat unique to Daifuku. The reciprocating STV technology in the older system is not unique in this function. The function has been built by a number of companies in the U.S. and Europe. The exact design of vehicle and aluminum rail is different.

The loop STV takes the place of a conveyorized front end. The acceleration and deceleration, up to and down from 270 fpm (80 m/m) top speed, provides a relatively high performance per vehicle. The throughput with twelve vehicles provides the required amount. This number was not obtained, but would be in the 120 in and 120 out per hour range.

The orders are entered in the host computer network linking the company's 30 offices in Japan. The system provides on-line inventory to permit making only the commitments that ORIX can fill. Although the company's normal order fill time is two days, ORIX provides same day service up to 2:00 p.m. About 50 percent of the company's orders, by number of instruments, use this same day service.

As the orders are filled, they are routed to a four-aisle AS/RS buffer storage on the first floor, providing 320 openings for order consolidation and staging ahead of packing and shipping (Fig. Orix.14). This provides ORIX the order and inventory control so common in Japan. This feature is only used by a few U.S. companies, but it is a part of the Japanese philosophy.

The packing department uses four different sizes of special cartons and large bubble pack (approximately 2" x 3" per bubble) strips to protect the instruments. ORIX has its own bubble-making machine.

ADDITIONAL OBSERVATIONS

The computer's control system hardware and software were done by Daifuku. Daifuku led the functional specification effort with significant input from ORIX personnel as to how they wanted the system to operate. This is true for the system below the host computer.

The material handling computer includes the system working inventory and controls the system strategy. Figures Orix.7 and Orix.8 show typical control panels for the S/R machines and end-of-aisle control, and Figure Orix.17 shows a typical group of conveyor control panels.

The total number of people at the distribution center may seem high until all of the functions provided are understood. The 260 workers have the typical large number of part-time help, but not as many as other places that the panel visited. This is due to the expertise required in some of the work. The center has only four supervisors, as well as three persons involved in maintenance.

There is one more single-aisle AS/RS for parts on the first floor. It provides 910 openings and is typical of mini-load systems found throughout the world.

Most shipments occur on Wednesdays, Thursdays and Fridays in order to meet the customers' desire to start projects on Monday. The company's receipts are normally on Mondays and Tuesdays.

Damaged shipments, when returned from user, are running at 5.3 percent. For obvious damage, ORIX bills the customer. If material (like cable) is short, ORIX sends a notice, but if it is not returned, the company does not bill. Most shortages are oversights and ultimately returned by the customer.

ORIX has a program in place to improve the company's productivity by 30 percent. In its first year, the company gained 20 percent.

SUMMARY

ORIX appears to be a very well run business providing valued service to high-tech Japanese industry. The company's performance is very good: ORIX has designed a very functional system with many automatic checking features and inventory control. The equipment is in excellent condition and has a very high reliability.

To many U.S. companies, the amount of equipment and automation would be questioned, but the smooth-running operating and service provided justifies the investment to the Japanese. This author's opinion is that forward-thinking U.S. companies would agree with the solution as long as they could get the reliability of operation found in Japan.

QUESTIONS ASKED BY PANEL

Q. What is the principal business of ORIX?
A. *The company's primary business is scientific instrument rental.*

Q. What is the size of the facility in square feet/meter?
A. *~ 110 m x 80 m, 8,800 m² land*
Receiving ~ 10, Shipping ~ 10 doors
26,000 m² is total of 5 floors.
~ 5,200 m² per floor counting AS/RS x 5
The Government of Japan considers every 5 m in height a floor.

Q. What is the sales volume of the facility?

A. *$320 million (¥42,500 million) is the total sales volume for the company.*

Q. Describe the facility throughput.

A.

Trailers Loaded	*Avg. 5 truckloads/day*
Trailers Unloaded	*1,000 units/day in about 5 trucks*
Lines Shipped (Broken Case, Full Case, Full Pallet)	*(Not obtained)*
Units Shipped	*1,200 units/day delivered to high-tech Japanese companies*
Orders Shipped	*500/day*

Q. Describe the storage capacity in terms of mini-load openings and floor storage, in sq ft/m.

A. *Mini-load openings:*
5 mini-load systems.
2 different load footprints, main storage systems.
2-8 aisle small loads, 3 heights; 140 mm, 300 mm, 500 mm; system -- 15 levels, 64 m long, 18 m wide.
1-7 aisle large loads, 2 heights; 300 mm and 500 mm; system -- 10 levels, 64 m long, 18 m wide.
83,000 openings in the 3 systems, each at 120 m/m travel, 60 hoist and 7 sec/fork; 2 of 3 systems served by 12 STV with speed of 80 m/m. Older 8-aisle system has independent delivery system.
1-4 aisles buffer, 320 openings, 5 levels, 8 columns long.
1-1 aisle small parts, 910 openings, 13 levels, 35 columns long.
5,000 openings in conventional racks. Some are moveable racks.

Q. What is the amount of the company's investment in material handling hardware and software?

A. *$23 million (¥3,000 million) in building*
$11.5 million (¥1,500 million) including inventory computers, not host (done by Daifuku with input from ORIX).
$2.3 million (¥300 million) in software and $230 thousand in hardware.

Q. Annual number of man-hours/employees
-management supervision; -direct operations

A. *Management supervision:*
1,800-2,000 hours/year; 4, and 3 people for maintenance; 2 times per year Daifuku comes for maintenance inspection.

Direct operations:
260 total, 170 employees, 90 part-time employees.

Q. Number of items (SKUs)
-stored; -processed, cross dock

A. *Number items -- 10,000 SKUs*
-stored -- 150,000 units; -processed -- none

Q. Improvements -- recent and planned:
-defect elimination; -productivity enhancements; -reduced cycle time;

A. *2 years old, original is 5 years old.*
To raise productivity by 30 percent by decreasing cost of inspection and implement equivalent automation.
First year, gained 20 percent.

Q. Productivity measures for:
-overall facility (units/man-hour); -truck unloading; -pallet putaway; -full case picking; -sortation; -packing; -truck loading

A. *Technical checking - 30 min/unit*
Picking, packing, etc. - 17 min/unit

Q. Accuracy measures for:
-inventory levels; -order picking; -shipping;

A. *Order picking -- less than 0.2 percent*
Shipping -- less than 0.5 percent, and includes picking

Q. Customer service measures:
-dock-to-stock time; -percentage of material cross-docked; -backorder percentage and fill rate; -order cycle time

A. *None; Will not take order if not in stock.*
Order by 2:00 p.m., out same day. 2-day lead time for manifest and quarantine in material handling computer to assure order. 50 percent are same day.
Average rental duration is 1-2 months.

Figure Orix.2. Overall view of return material inspection. All conveyor is gravity-type and built by Daifuku. The view shows the OA (Office Automation) machine test zone.

Figure Orix.3. The vertical lift delivers product to the third or fourth floor, depending upon type of operation. Each tray can be coded for routing to the correct floor and location.

Figure Orix.4. A closeup of a Daifuku sorting transfer vehicle (STV) in the loop in front of one of the three mini-load storage areas.

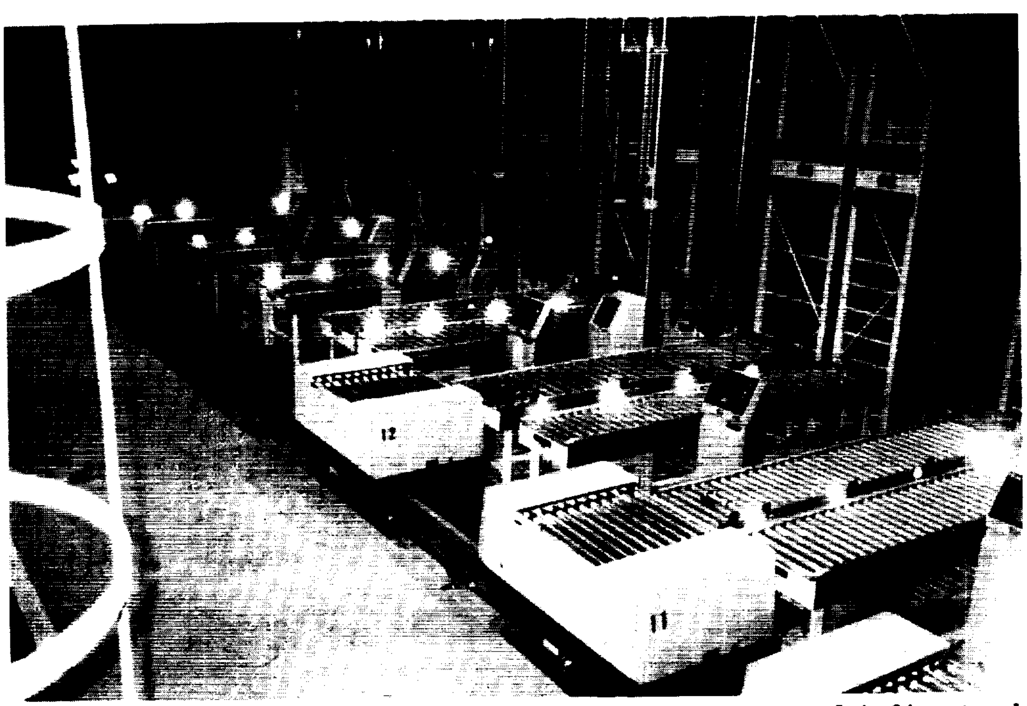


Figure Orix.5. The overall front end of the new eight-aisle mini-load system. It is 64 meters long, 18 meters wide and 15 levels high. There are twelve STVs in the delivery system.

Figure Orix.6. (Left) The return loop of the STV system, with the maintenance transfer out section in the middle of the picture. The collectors are shown inside the left rail and the two aluminum rails for vehicle support. STVs are motor-driven, not LIM. STVs operate at 80 meters per minute.

Figure Orix.7. (Below) Closeup of the end-of-aisle control station for diagnostics and single-aisle local operation.

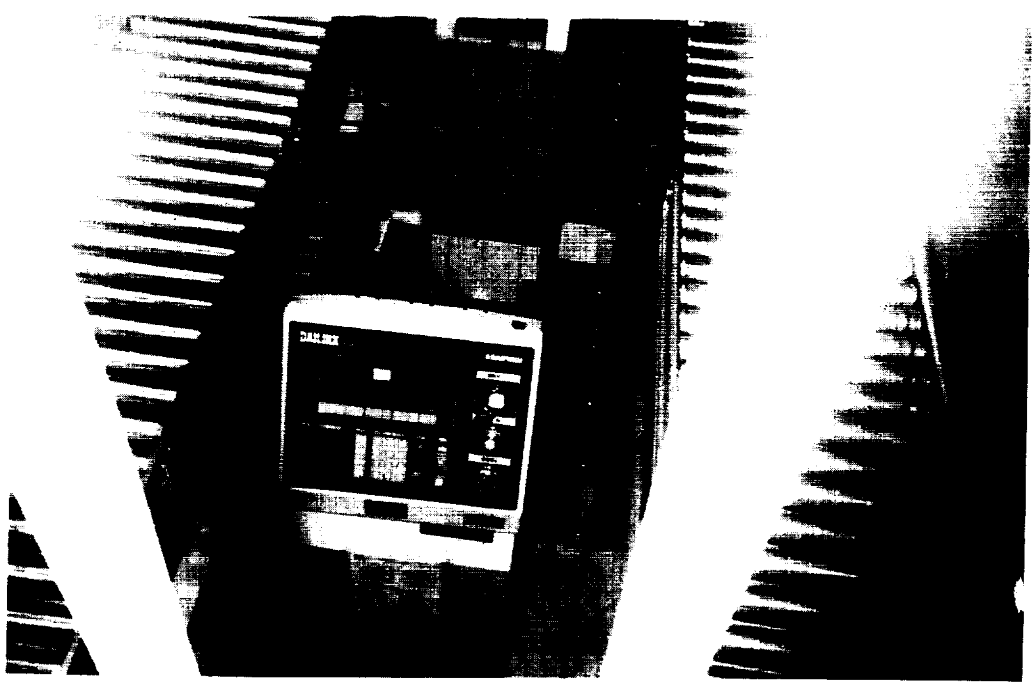


Figure Orix.8. (Left) The on-board control on the mini-load machine with the shuttle forks (7-second cycle) picking up a load. Also notice the safety hook for some maintenance man to use with the ladder on the machine.

Figure Orix.9. (Below) The two typical shipping boxes for ORIX equipment. The larger ones, in the stacks, are for most equipment, but the smaller one being held is for lap-top computers.

Figure Orix.10. The operator using a hand-held scanner to read the product serial number to maintain inventory information.

Figure Orix.11. The hand-held scanner, as well as the photo eyes used to check the various heights of the loads for most effective use of cube in the storage system.

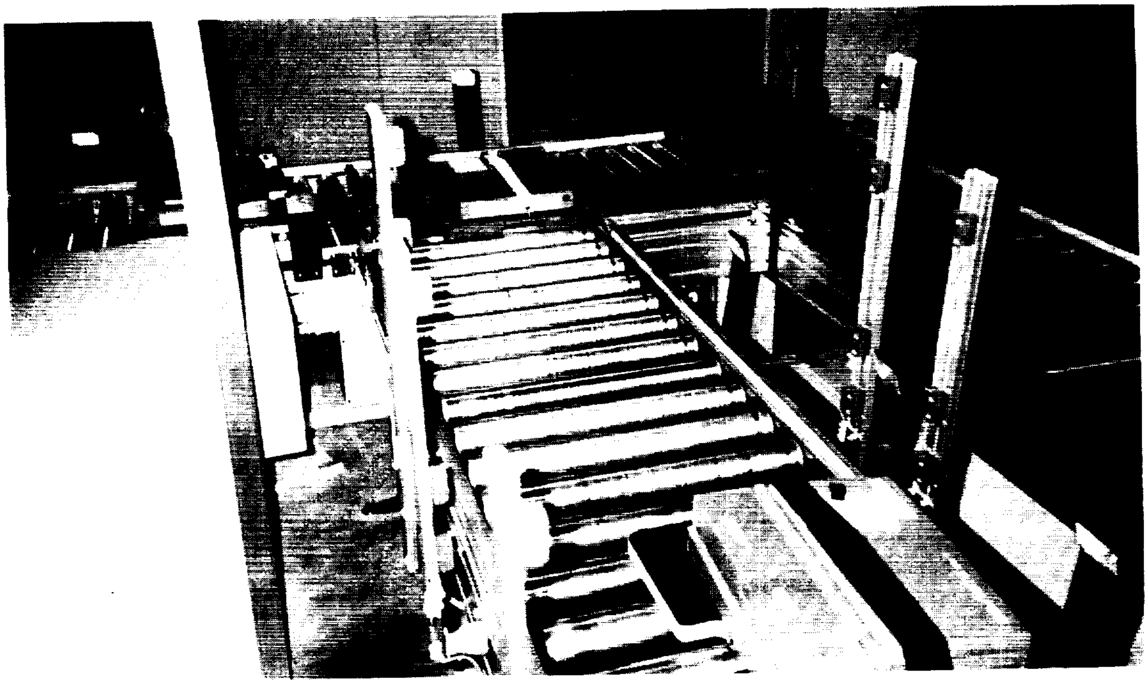


Figure Orix.12. Powered roller conveyor with height checking.

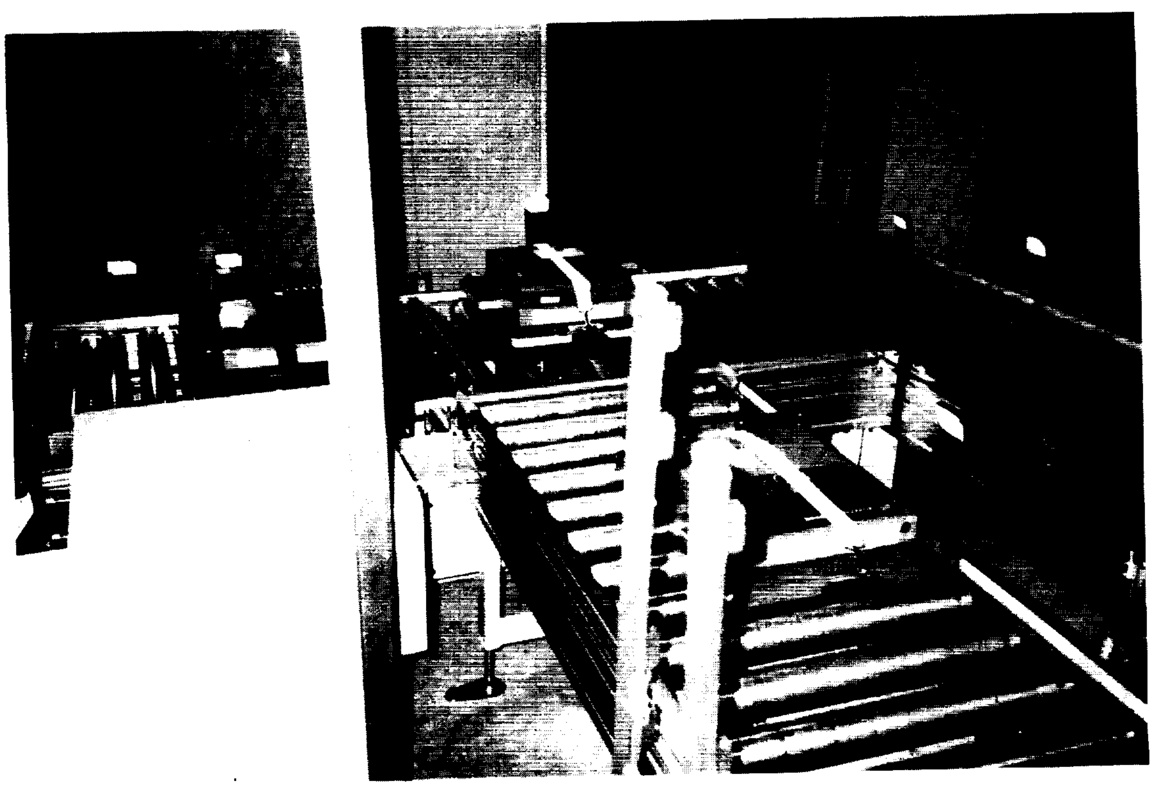


Figure Orix.13. Variety of loads with accessories. Note lap top computer in the background strapped to one tray (slab).

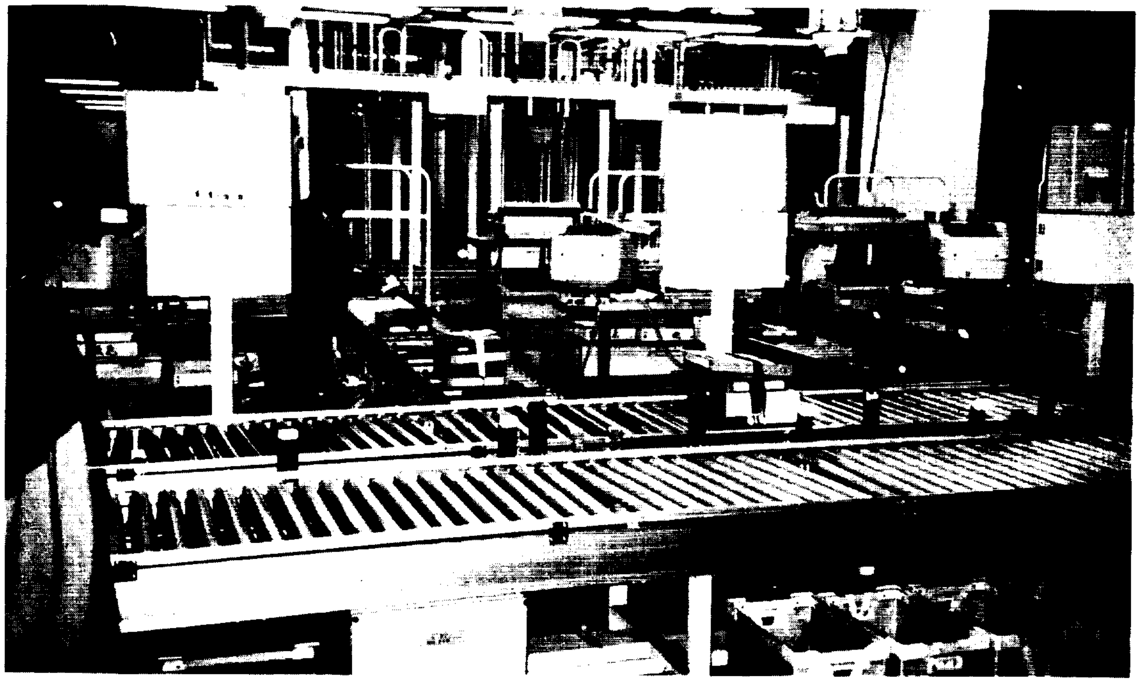


Figure Orix.14. Front end of a four-aisle mini-load buffer system, which accumulates the customer orders ahead of the packing and shipping departments.

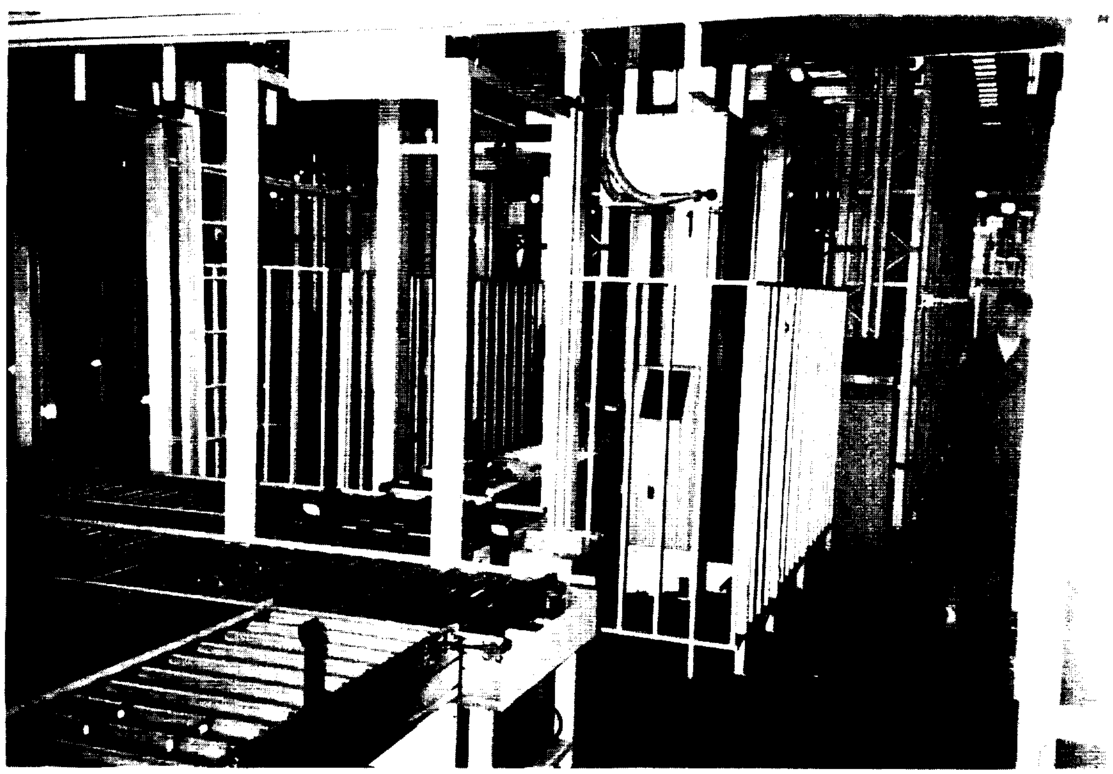


Figure Orix.15. One of the four aisles in the buffer system, which accents the idea of small effective systems. It is eight storage columns long and five levels high, providing 320 openings total.

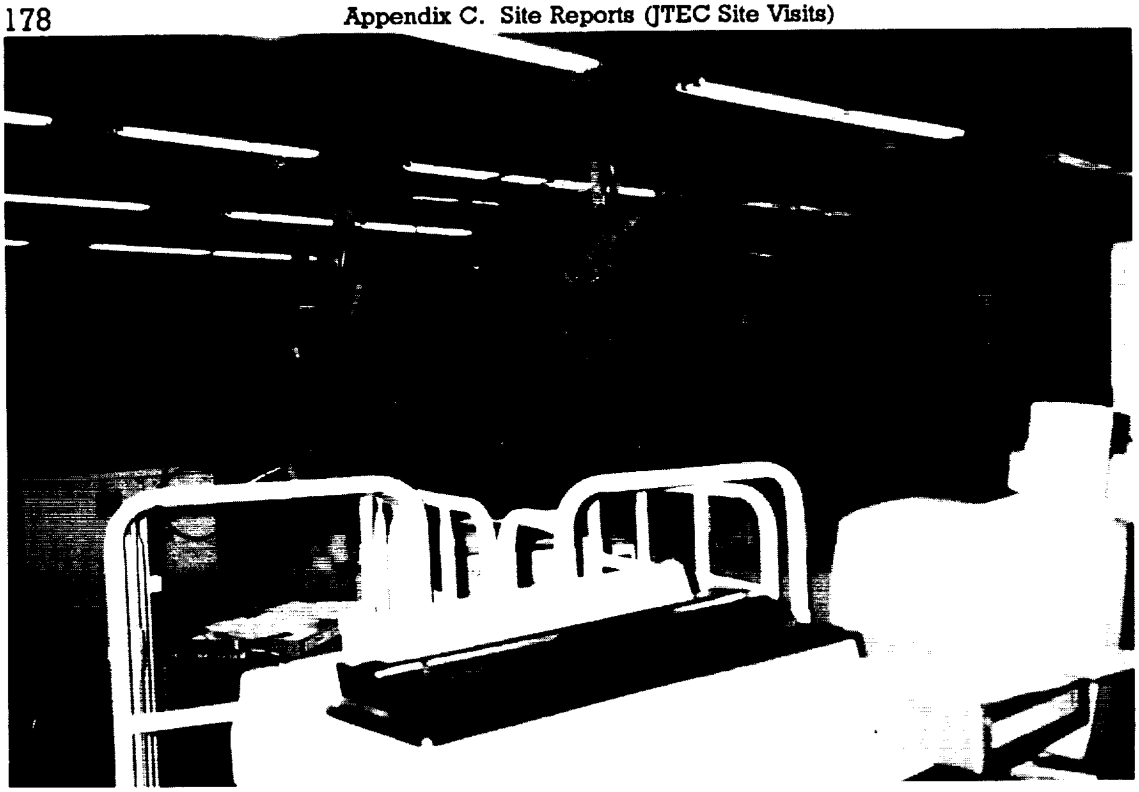


Figure Orix.16. The company's automatic bubble making machine. Bubbles are used for packing in the special ORIX shipping boxes.

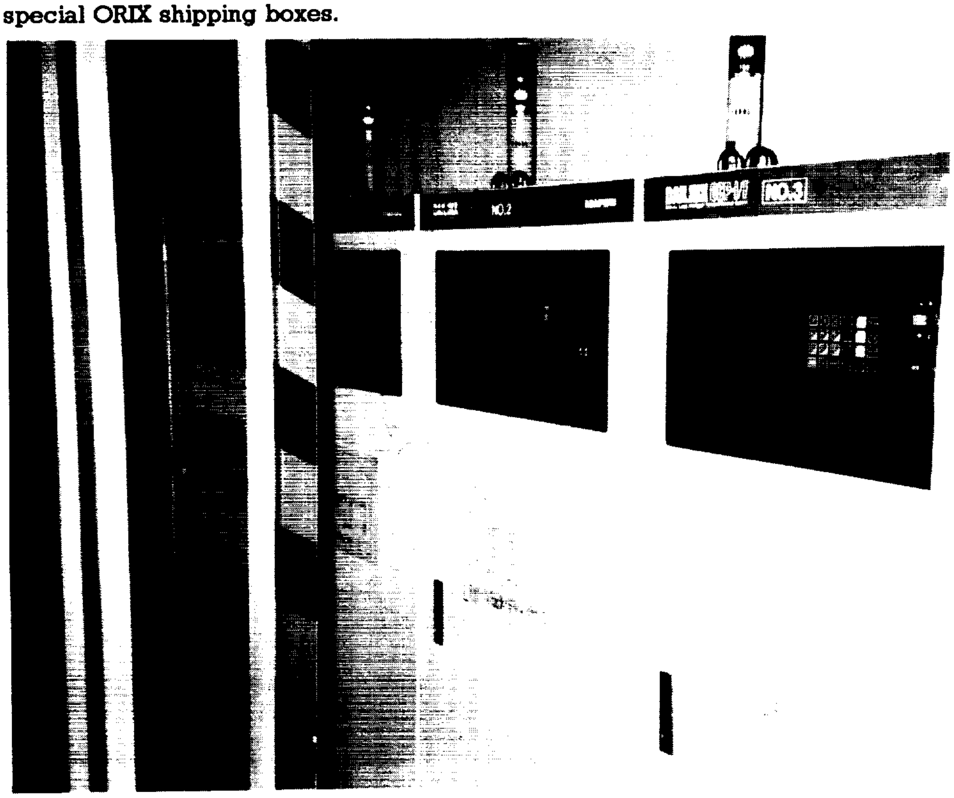


Figure Orix.17. Typical Daifuku control panels, with a small screen and keyboard in the top of each panel. The layout of the area controlled is in the middle of the front door.

Figure Orix.18. (Left) A robot lifter used to assist packing people with the heavier scientific instruments or computers.

Figure Orix.19. (Below) Front end of the older eight-aisle AS/RS system, with the chain-type conveyor P&D stations that operate with a reciprocating STV. The eighth S/R machine is shown picking up a load in the background.

Site: **Fuji Logitech, Inc.**
Fukuroi Branch
293-1 Oyama, Fukuroi-shi
Shizuoka, Japan

Date Visited: April 9, 1992

Report Author: A. R. Voss

ATTENDEES

JTEC:

R. Ward
L. Martin-Vega
A. Voss
H. Zollinger
B. Williams

HOSTS:

T. Suzuki	President
S. Mochizuki	General Manager Secretarial Department
A. Sone	Secretarial Department

MATERIAL FLOW AND TECHNOLOGY EMPLOYED

Fuji Logitech is a full-service public warehouse company the services of which include logistics. Fuji Logitech maintains 290,000 square meters of warehouse space throughout Japan. The company also operates in the U.S. The site the JTEC team visited was one building in a complex of warehouses. It has approximately 65,000 square meters on two floors and employs about eight people. The first floor is used to receive washing machines from manufacturers. The washing machines are unloaded using fork trucks fitted with large clamps for picking up 8 to 12 packaged washing machines at a time. Each load is delivered to an input conveyor servicing an elevator going to the second floor.

As the load is placed on the input conveyor, a bar code label is read into the control PC that starts the tracking/locating process. When a load of washing machines reaches the second floor, it is moved onto a 13-foot exit conveyor. The loads are then picked up by one of three offwire guided robot forklifts (AGVs) also equipped with large clamps. These AGVs have been in service for approximately five years

C-3.

and are affectionately called the "nightshift." The AGVs then stores the loads in one of the predetermined locations on the second floor, which is approximately 30,000 square feet in area. The storage locations consist of deep lane block stacking off the 15-foot main service aisle. The lane locations are controlled by a PC that keeps track of where the loads are stored in an x-y-z grid. The z dimension is critical because the palletless loads are double stacked so that each lane is three washing machines wide and four washing machines high.

After all the washing machines are unloaded from the 40 daily delivery trucks and stored on the second floor of the warehouse, the workers go home. The AGVs work all night sorting and staging the orders for the next day's 70+ truckloads shipping to customers. About 8,000 washing machines are handled daily by manned forktrucks and AGVs. At night the AGVs stage approximately 1,000 washing machines. The AGVs work unattended except for a twice daily battery change, which takes about five minutes.

Two of Fuji Logitech's 120 programmers wrote the code for the robot forklifts. Having Fuji programmers write the program let the company avoid building a more expensive AS/RS facility. Fuji estimates that the forklift robot system cost less than 50 percent of an AS/RS facility.

The panel visited another installation at the Fuji branch where a three-way stacker robot forklift with a rotating turret operates the cold storage facility. This unattended facility is different in that the AGVs pick loads from a conveyor and then store each frozen load in one of three narrow rack aisles. As the AGV approaches one of the aisles, it automatically opens the sealed doors. Then the AGV proceeds to the specified rack location. After depositing the load on either side of the aisle, the AGV reverses itself and drives out of the cold (-25°C) storage facility and closes the doors, ready for the next command. Using an AGV forklift for this type of work solves the problem of humans having to withstand the cold temperatures. This improves the labor environment.

RESEARCH AND DEVELOPMENT

T. Suzuki's future vision is to modify the current operation at the two locations that the panel visited so that the robots can load and unload the trucks as they arrive at the dock. He has challenged his staff and himself to seek an innovative approach to solving this last piece of the puzzle.

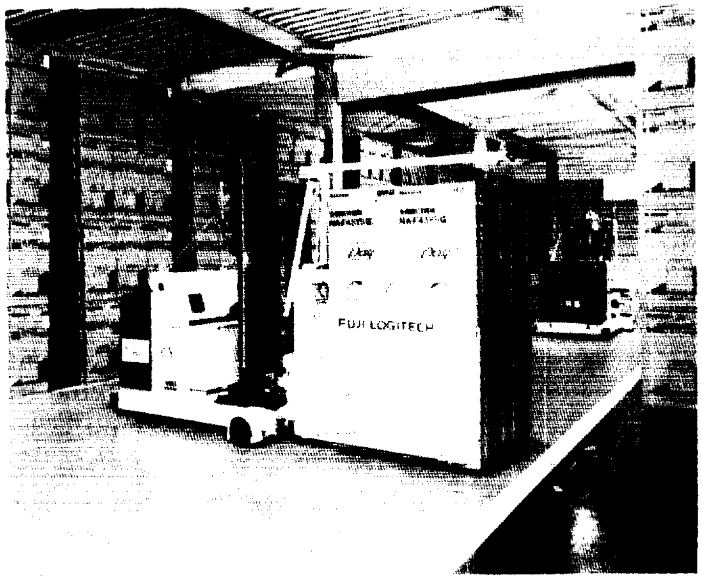


Figure Fuji.1. Robot forklifts with carton clamps (Fukuroi Branch) that can directly pick up and clutch cargoes. The simultaneous operation of these three enhances labor efficiency remarkably. A fully-automated cargo handling system that uses robot functions releases operators from hard night work.

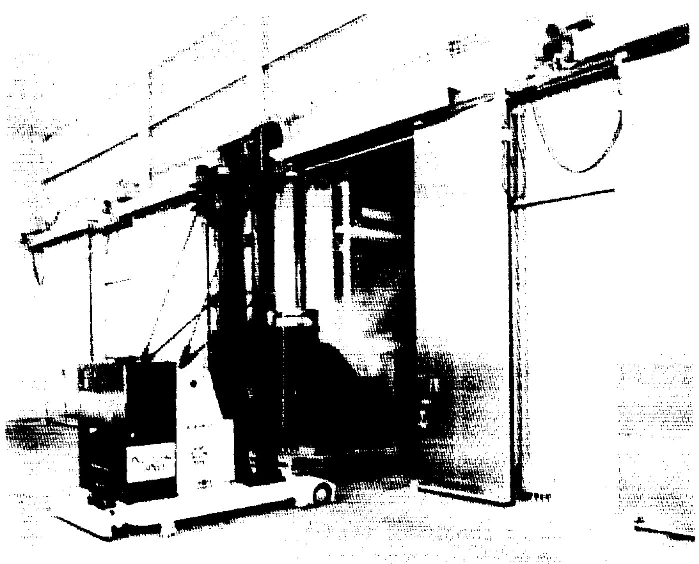


Figure Fuji.2. Three-way stacker robot forklifts with box-type pallets and their dedicated racks realize the increase of storage capacity. Under the improved labor environment, workers have been released from hard work in a freezing chamber (-25 °C). Their continuous operation has also improved efficiency.

Site:	**Ishikawajima-Harima Heavy Industries Co. Ltd. (IHI)** **Shin Ohtemachi Building, 2-1 Ohtemachi** **2-chome, Chiyoda, Tokyo 100, Japan**
Date Visited:	April 10, 1992
Report Author:	A. R. Voss

ATTENDEES

JTEC:

R. Ward
L. Martin-Vega
A. Voss
H. Zollinger
C. Uyehara
B. Williams

HOSTS:

Y. Matsuyama	Manager, Physical Distribution Systems Div.
M. Omori	Manager, Materials Handling Equipment and Physical Distribution Systems
M. Nitta	Assistant Manager Sales-International Operations
M. Murasugi	Sales-International Operations

BACKGROUND

Ishikawajima-Harima Heavy Industries Co. Ltd. (IHI) was established in 1853 as the Ishikawajima Shipyard. Through the years it has changed its name until 1945, when it became IHI. IHI supplies a wide range of products to Japanese industry and society. IHI's corporate ideal, which is to contribute to society, is handed down from generation to generation. IHI has approximately 15,300 employees, 17 plants, 29 branch and sales offices, and 92 major affiliated companies in Japan.

IHI also has 36 overseas operations consisting of 12 offices, 8 subsidiaries and 16 joint ventures. Annual sales for 1991 were $5.6 billion. The sales breakdown was:

25% Energy and chemical plants
19% Physical distribution systems and steel structures
(the steel structures are believed to be racks and shelving)
18% Aero-engine and space development
15% Shipbuilding and marine engineering
12% Mass-produced machinery
11% Industrial machinery

IHI has $500 million in capital to support and finance the broad scope of its business. Some of IHI's "firsts" are:

- First steamship built by a Japanese shipbuilder (1877)
- First Japanese steel bridge (1883)
- First 80 hp air compressor (1892)
- First Japanese thermal power plant (1896)
- First four-ton open-hearth furnace (1916)
- First Japanese jet engine (1945)
- First Japanese mobile offshore drilling platform (1958)
- First FREEDOM series standardized multipurpose dry cargo carriers (1967)
- World's first barge-mounted polyethylene plant (1981)
- World's first mobile artificial island-type oil rig (1984)

IHI develops, manufactures and supplies products in space development; power plants; environmental preservation and disaster prevention; jet engines; storage facilities and process plants; bridges, steel structures and construction equipment; mass produced machinery and consumer products; shipbuilding and marine engineering; industrial machinery; leisure equipment; computer software; business development; and, material handling equipment and physical distribution systems.

Traditionally material handling equipment and transportation equipment have been among the major products of IHI, making it one of the leaders in the market. In terms of material handling equipment alone, it ranks third among equipment manufacturers. However, this ignores IHI's dominance in crane manufacturing which, when considered, moves the company much higher.

IHI designs and manufactures a variety of cranes, including container cranes, ship loaders and unloaders, pneumatic unloaders, and stackers and reclaimers. IHI is ranked among the top crane manufacturers for handling containers, mineral ores, coal and grain at ports around the world. IHI also manufactures cranes for factories and nuclear power plants.

IHI's Physical Distribution Systems Division includes equipment consisting of AS/RSs, AGVs, overhead wagons, sorters, and picking conveyors. The company also supplies complete systems and robots for factory automation (FA). Some of IHI's deliverables in 1991 were:

- Continuous unloader to Reynolds Metal for its smelter operation in Texas
- 120 metric ton hydraulic double-deck crane for Shin Kurushima Dockyard Co.
- 7,600 metric ton per hour coal-handling system for the Matsura Thermal Power Plant
- 300-car park tower for Robinson's Department Store
- 6,050 vehicle storage and access automatic stacker warehouse for Chiba Toyopet
- -30°C automated food warehouse

IHI has done factory automation for the following industries:

- 24-hour nonstop plate glass production and marshalling line
- Parts supply system for an electric washing machine assembly line
- Batch process-type manufacturing for a coffee processing line
- In-process storage system without rigid racking for an aluminum building materials manufacturing line
- Multistory storage system for an advanced new car service center
- System for controlled atmosphere fruit storage

IHI will be building a fully-automated warehouse for Mercedes-Benz Japan Co. Ltd., which will stock 100,000 automobile parts and components. In addition, Mazda has ordered an automated handling system for a transfer press line.

The Physical Distribution Systems Division has approximately 150 employees spread over three major functional areas. These engineers are primarily mechanical engineers who are trained by IHI for three years.

Approximately 50 percent of IHI's physical distribution projects are for manufacturing operations and the rest is for distribution operations. If broken down further, 20 percent is for manufacturing, 40 percent for distribution, and 40 percent for buildings.

Physical Distribution Systems Division		
FA System Eng Group	Technical Specialist Group	Project Mgmt. and Procurement

RESEARCH AND DEVELOPMENT

The panel's visit was confined to conference room discussions, which consisted of viewing a video produced by IHI describing the company's broad range of businesses, and a transparency presentation. The panel did not see any of IHI's material handling production facilities or the company's most recently developed equipment. IHI hinted that other areas of the company were doing R&D, but would not elaborate except to allude to work in the area of artificial intelligence.

SUMMARY

In 1991, IHI showed solid growth in each of its major operations for the third consecutive year. Net sales climbed almost 20 percent to ¥966.8 billion ($7.4 billion). Sales in Japan represented 85 percent of the total sales, while the rest came from overseas operations.

Site: **Yamatane Oi Distribution Center**
3-18 4-Chome
Toyai Otaku 143
Tokyo, Japan

Date Visited: April 7, 1992

Report Author: A. R. Voss

ATTENDEES

JTEC:

R. Ward
L. Martin-Vega
A. Voss
H. Zollinger
B. Williams

HOSTS:

T. Nagasao	Executive Vice President
K. Takahashi	Assistant General Manager
N. Nakanishi	Executive Sales Coordinator

BACKGROUND

Yamatane Corporation was established in 1937 as the Tatsumi Warehouse Company Ltd. In 1940, Taneji Yamazaki acquired the right of management and formed the Yamatane Group, a collection of companies and activities very diverse in nature. The main businesses of Yamatane Corporation are public warehousing and logistics, rice milling and wholesaling, software sales of distribution information and warehousing control systems. The Yamatane Corporation ranks seventh in distribution activity based on sales volume in Japan. The long years of experience and expertise of its people assure a high level of distribution services. In terms of sales, the company generated $138.5 million from the warehouse/distribution business; another $22 million from distribution systems software sales to other companies; and $230.8 million from rice milling and wholesaling.

MATERIAL FLOW AND TECHNOLOGY EMPLOYED

The distribution center that the JTEC panel visited was one year old. The AS/RS and case flow delivery system were supplied by Seibu Electric, which served as the system integrator and worked closely with the Yamatane staff during the design phase. The center receives, stores, picks and ships a variety of consumer durable goods and foodstuffs, including electronics, wine, jelly, tea, coffee, and so forth, to 17 strategically located smaller distribution centers around Japan. Handling various lines of goods helps stabilize business during cyclical ups and downs. For instance, foodstuffs provide a buffer against recession, when durable goods are not as much in demand. This distribution center is built on rented land measuring 9,551.7 square meters. The total floor space is 17,143.8 square meters spread over seven floors. The facility occupies a footprint of 5,200 square meters. The distribution center cost about $23.8 million to build. About 50 percent of the investment was for the building and 50 percent for the material handling equipment. The facility was designed to handle distribution activities into the 21st century.

Simulation was used to model the warehouse. The warehouse stores 4,640 SKUs in as many AS/RS rack openings. The racks are serviced by five cranes, 89 units of conveyor, and two sorting transfer cars. All of the receiving is done utilizing 1,100 mm x 1100 mm pallet loads. Only 10 percent of the shipping volume is done utilizing pallet loads. The rest consists of 65 percent case shipments and 25 percent broken case shipments.

Approximately 700 SKUs represent 80 percent of the shipping volume. An AS/RS stores pallet loads of consumer durable goods and foodstuffs. The AS/RS consists of five cranes servicing a rack supported building. Most of the pallet loads are broken down to replenish the case picking AS/RS and the broken case picking area.

Case picking is done on the sixth floor using a flow rack system with 684 openings. Two AS/RS cranes pick cases from the flow racks and another crane fills the flow racks. The picked cases move down a paternoster to a transfer conveyor. Broken case picking is done using flow racks and a pick-to-light system that indicates which SKUs to pick. The broken case SKUs are picked into plastic bins that have been set up by an automatic bin erector. After the bins are filled with orders, they are conveyed to a packing area where the SKUs are priced per the department store's requirements. The SKUs are removed from the plastic bins and packaged into shipping carton cases. The carton cases are then conveyed to the shipping dock, where they are sorted by a narrow belt sortation conveyor into 14 lanes and readied for loading into carts and onto waiting trucks.

Block stacking is done in another part of the facility that the panel did not spend much time viewing.

The warehouse staff consists of 40 employees who earn from 2,000 to 4,000 yen ($15-30) per hour, depending on whether they are warehouse workers or equipment operators. The office staff has 30 employees who take orders and handle customers. There are no maintenance personnel on site. Seibu Electric is under contract to perform monthly maintenance.

SUMMARY

There does not appear to be any research underway at the site. It is a highly automated facility aimed at reducing labor problems and costs while meeting customer demand.

Figure Yamatane.1 Illustration of one automatic case picking system used in conjunction with a car-on-track system.

Site: **Nippon Shuppan Hanbai Inc.**
Oji Distribution Center
Oji, Japan

Date Visited: April 6, 1992

Report Author: E. Frazelle

ATTENDEES

JTEC:

J. Apple
T. Day
E. Frazelle
G. Petrina
C. Uyehara

HOSTS:

Minoru Kubutsu — Deputy Manager, International Division, Nippon Shuppan Hanbai Inc.

Minoru Kikegawa — Assistant Manager, Tokyo Systems Sales Department, Tsubakimoto Machinery

BACKGROUND

Table Nippon.1
Background

Industry	Wholesale book & magazine distribution. By law, all books and magazines must be available in retail outlets on the same day throughout Japan. Regulated pricing dictates that the pricing of books and magazines cannot vary by location.
Sales	¥600 billion in 1991
Share	35%
Network	18,000 retail outlets; 3,000 suppliers/publishers
Age	43 years
Margin	8%

FACILITY PROFILE

Table Nippon.2
Facility Profile

Sales	¥600 billion
Items	75,000 book titles in stock; 2,500 magazines. There are a total of 600,000 book titles in Japan; 150 new titles are introduced each day. There are 3 paperback footprint dimensions in Japan.
Size	Approximately 350,000 sq. ft.
Stories	5
Throughput	Magazines - 5,000,000 copies per day New book titles - 8,000,000 copies per day Existing book titles - 450,000 copies per day
Stock	2,800,000 copies

MATERIAL HANDLING SYSTEMS

Tsubakimoto Paperback Multi-Sorter (November 1989)

The Tsubakimoto Paperback Multi-Sorter handles batch picking for sorter induction of paperback books. Sixteen induction stations (eight stations per side) use OCR readers for a single read per title automatic induction. The primary sort is one of 10 sortation lanes, each equipped with 150 sortation chutes. Each chute automatically prepares paperback stacks. A photocell monitors the height of each stack and indexes a completed stack to an accumulation point. Stacks are manually packed into shipping cartons. The total sortation capacity is 43,200 copies per hour. The total investment is approximately $20 million ($463 per sort per hour). The multi-sorter is unique to the industry.

Speaker Sorters

Two traditional tilt-tray sorters are used to sort all other books. Each is approximately 600 feet long, operates at a speed of 350 feet per minute, and is equipped with 130 chutes. The sorters are used for a primary sort. The final, secondary sort is done manually with staging in conventional bin shelving. One sorter is keypad inducted; the other is voice inducted. Again, each sorter is fed with a batch-picking operations.

Industrial Vehicles

60 forklift trucks and 20 lowlift trucks

Investment

The material handling hardware investment is estimated to be $25 million at $71 per square foot (at ¥130 per dollar).

Motivation

The design was motivated by limited labor availability and the limited variation in the dimensions of Japanese paperback books.

INFORMATION SYSTEMS

Nippon Online Communication System (IBM, April 1984)

As of the time of the JTEC panel's visit, forty percent of Japanese book stores were ordering through point-of-sale terminals; that figure was up from only nine percent in two years. The remaining use order slips placed in each book by the publisher. The order slips are mailed to Nippon, serving essentially as a *kanban*. Each order slip contains the book's title, author, price, and ISBN in optical character format.

Optical Character Recognition

Since Japanese publishers are just beginning to place bar codes on books, OCR is the current form of automatic identification. An OCR reader at Nippon is capable of reading 2,000 order slips per minute (REI, Trace 100).

STAFFING AND PRODUCTIVITY

Staffing (1,300 Total)

- Full-time:	500	Other:	800
- Direct:	1,200	Other:	100

Productivity

Overall 140 lines per hour

SERVICE LEVELS

Fill Rate

75 percent of orders are filled from stock

Order Cycle Time

In-stock: 2 to 3 days
Out: 7 days

Site:	**Ohki Distribution Center, Ageo** **c/o Ohki KK** **2-1-4 Otoha, Bunkyo-ku** **Tokyo 112, Japan**
Date Visited:	April 8, 1992
Report Author:	E. Frazelle

ATTENDEES

JTEC:

J. Apple
T. Day
E. Frazelle
G. Petrina
C. Uyehara

HOSTS:

Yoshio Ishikawa	Director, Physical Distribution Planning, Ohki
Katsumi Hasegawa	Branch Sales Manager, Okamura

BACKGROUND

Table Ohki.1
Background

Industry	Drug manufacturer and wholesale distribution
Sales	¥51.5 billion in 1991
Share	10% of OTC market = 3rd largest in Japan
Network	11,000 retail outlets, 5 distribution centers
Age	338 years

FACILITY PROFILE

Table Ohki.2
Facility Profile

Sales	¥20 billion
Items	25,000 on record; 6,000 active
Size	50,000 square feet
Stories	2
Throughput	20 trailers inbound per day 20-30 trailers outbound per day 1,000 orders per day 10,000 broken case lines per day 2,000 full case lines per day 20 full pallet lines per day

MATERIAL HANDLING SYSTEMS

Receiving and Putaway

Direct putaway of palletized loose cases into a two-aisle, 560-opening AS/RS (end-of-aisle controller).

Storage

Full cases are stored on pallets in the two-aisle pallet AS/RS. Loose items are stored in totes in a rotary rack carousel (Okamura). The rotary rack carousel system has two seventeen-level carousels with a laddermatic input/output device.

Picking

Broken case picking is executed with a progressive order assembly into totes. An order/tote begins in a bin shelving area where 70 percent of the items are stored. These are the least popular items in Ohki's distribution center. Picking is light-directed with order pickers picking into multiple totes/orders in the bin shelving zone. Once complete, the totes are placed on roller conveyor that transports the totes through several bays of gravity flow rack. The gravity flow rack houses five percent of the SKUs, the most popular in Ohki's DC. Again, picking is light-directed, with each picker assigned to a single bank of gravity flow rack. The final picking zone is a series of three pick-from-storage stationary picking stations. Storage totes are transported to/from the picking stations from/to the rotary rack carousel. Stationary pickers are light-directed and pick up to three totes/orders at a time.

Investment

The material handling hardware investment was ¥300 million or $46 per square foot (at ¥130 per dollar). A typical automated dispensing system for wholesale drugs costs approximately $25 per square foot.

Motivation

The design was motivated by high space costs, labor shortages, and increasing customer service requirements.

Design Alternatives

An automated dispensing system was considered, but was ruled out because of the variety of product sizes in Japan's wholesale drug market, labor intensive replenishment, and high initial cost.

INFORMATION SYSTEMS

Host

IBM AS 400 -- Recently introduced electronic order entry via point-of sale terminals.

STAFFING AND PRODUCTIVITY

Staffing

Management	5,880	hours/year	(2)
Supervision	12,250	hours/year	(4-6)
Operators	21,440	hours/year	(10-15)
Totals	39,570	hours/year	(16-23)

Productivity

Overall	75	lines/hour

Note that 60 lines per hour is outstanding productivity in U.S. wholesale drug distribution.

Site: **Suntory Tonegawa Brewery**
2712 Kurakake Akaiawa
Chiyoda-Machi Ohra-Gun
Gunma-Ken 370-05, Japan

Date Visited: April 10, 1992

Report Author: G. J. Petrina

ATTENDEES

JTEC:

G. Petrina
E. Frazelle
J. Apple
T. Day

HOSTS:

Keizo Tamagawa	Manager, Administration, Tonegawa Brewery
Kaz Fujio	Assistant Manager, Planning and Systems Department, Distribution Division
Shigeru Fujita	Tonegawa Brewery
Tokuji Matsudaira	Tonegawa Brewery

BACKGROUND

Suntory, Ltd. was founded in 1899. The company launched Japan's wine and whiskey industries and pioneered the domestic beer industry. Today, Suntory is a highly diversified international corporation with operations in alcoholic and nonalcoholic beverages, food, and pharmaceuticals. The company also manages restaurants and sports facilities, and sponsors a variety of social and cultural events. Suntory, Ltd.'s net sales for 1990 were ¥796,445 million ($5.9 billion).

The Suntory Tonegawa Brewery produces Suntory's Malts, Namaginjo, and light beer. Budweiser and Carlsberg are also produced there under license from their respective U.S. and European owners.

The facility opened in February 1982 after a two-year planning effort and 16 months of construction. Operations were expanded in 1989 with additional facility construction. The overall site is 240,000 square meters (59 acres) in area with

101,000 square meters (25 acres) of floor space. The current throughput averages 50,000 cases per day (shipping capacity) with a maximum throughput capability of 200,000 cases per day. IHI, Toshiba, and Okura were the contractors who supplied the ¥2.7 billion (approximately $19 million) of material handling equipment for this facility.

MATERIAL FLOW AND TECHNOLOGY EMPLOYED

The panel only visited the warehouse/distribution center portion of the facility. It was the only one-story warehouse operation that the panel saw during the week in Japan, which may be attributed to the fact it was over an hour train ride from Tokyo.

The two large one-story warehouses were linked to the bottling plant by conveyor, which fed the cases directly to one of six automatic palletizers found in the warehouse. During the panel's visit, plastic cases of long-necked bottles were palletized six cases high. The pallet then passed through a device that wrapped and knotted a light cord around the top six cases to add stability to the load. Pallets were then loaded onto a car track system for delivery to storage or shipping. As in the United States, a first-in, first-out (FIFO) system is used for all products. Forklifts are used to bulk stow the pallets in designated areas of the warehouse. Smaller quantities of certain brands are palletized and stored in racks. Bottled beer was delivered in plastic cases while cans were in cardboard cases.

Order picking is computer controlled and done by various means. Case picking is done via forklift equipped with real-time video display terminals (VDT) fed information by RF from the mainframe. Forklifts also have two-way radios for any clarification or other information transfer that is necessary.

Orders are also filled by a totally integrated, unmanned AS/RS and tier picker combination. At the beginning of the day, the required pallets identified by the computer control are delivered by forklift to the AS/RS. To fill orders, the AS/RS retrieves a pallet and it is conveyed to a tier-picking device that strips the required number of cases for that order. These cases are repalletized, and the source pallet is returned to the AS/RS. Product is continually retrieved from the AS/RS until the pallet/order is complete and it is conveyed out of the system. All of the cases that the panel saw in this system were cans in cardboard boxes. Suntory and Toshiba worked together to design and build this AS/RS case picker system.

Inbound trucks first arrive at the truck guidance system located along the main entrance road. Under a covered shed, without leaving his vehicle, the driver inputs his transportation company number and truck number and is directed to one of thirty-three ground-level dock locations. All docks are totally covered so that the entire truck can be easily loaded during inclement weather. Most trucks that the panel saw were the gull-wing type. If on arrival their orders are not ready, truck drivers are instructed to go to the drivers' lounge. When the order is ready, a TV screen in the lounge will tell the driver which dock to report to. When the truck is loaded, the computer system is updated, and the driver leaves with his manifest to make his deliveries.

The panel was informed that the forklift operators were not Suntory workers. An independent contractor supplies operators based on the facility's need for that day or week.

SUMMARY

The Tonegawa Brewery is a highly automated and partially mechanized facility. Stock control is of utmost importance, and the computer system does a good job of maintaining that control. Our briefers indicated that the manufacturers of the systems provided the software and continue to maintain it.

Site: **Yokohama Distribution Center**
Okamura Corporation
c/o Sanno Grand Bldg.
2-14-2 Nagata-cho
Chiyoda-ku, Tokyo 100, Japan

Date Visited: April 8, 1992

Report Author: G. J. Petrina

ATTENDEES

JTEC

E. Frazelle
J. Apple
T. Day
C. Uyehara

HOSTS:

Masao Ishiwata	Chairman, Okamura
T. Shingenobu	Director, Yokohama Distribution Center
Masao Suzuki	International Marketing Manager
Yoshikazu Yamashita	Engineer, Mater. Handling Equipment Mktg. Div.
Kiyoshi Uetake	Manager, Mater. Handling Equipment Mktg. Div.

BACKGROUND

Okamura Corporation was founded in 1945 by 14 aeronautical engineers. Masao Ishiwata, one of the original founders, now serves as chairman of Okamura. The corporation has produced a variety of products over the years starting with pots and pans in 1945 and evolving to furniture, torque converters, material handling equipment, automobiles, and even airplanes. Today the company concentrates on producing furnishings for the home, the office, the laboratory, public meeting areas, and store display equipment. The company also designs and manufactures material handling and distribution systems for all types of products and industries, including software development, installation, and integration. Okamura also manufactures air-conditioning systems and prefabricated restrooms while continuing to supply its high technology torque converters for use in industrial and construction equipment around the world. Okamura's net sales for the year ending March 31, 1991 were ¥181,938 million ($1.29 billion).

The Yokohama Distribution Center was completed in 1991 -- taking three years from initiation of design to completion. The center consists of a five-floor administrative building, a vehicle control center, a rack supported AS/RS facility, a four-story warehouse, and a security facility at the front entrance.

The Yokohama Distribution Center is the hub of operations for Okamura, and acts as a central depot for dispatching goods for all of Japan. Much of the imported furniture, such as desks, chairs, and storage units, is stored at this facility for delivery throughout Japan. Approximately 3,300 items originating from Okamura's factories and suppliers are stored there.

MATERIAL FLOW AND TECHNOLOGY EMPLOYED

As a supplier of material handling systems, Okamura has created the Yokohama Distribution Center as a showplace of its capabilities. The total center is highly automated/mechanized and makes extensive use of bar coding for controls.

Trucks entering the facility first interface with the vehicle control system. This dock control system has a real time visual depiction of the status of all eighty-two truck docks. A 36" TV located in the truck control center depicts the facility and all its dock locations. Trucks are shown in various colors to indicate status, such as loading, unloading, awaiting manifest, and so forth. Drivers report to the control facility and are assigned a dock for loading or unloading. Incoming drivers are given a bar code manifest list. During unloading, the bar codes are affixed and used to control all future movement of the pallet throughout the facility.

The AS/RS was built as a rack-supported facility connected to the four-story warehouse facility. Seven cranes with a 600 kg (1,300 pound) lift capacity service the 10,192 pallet locations. The AS/RS is used primarily to store desk components that are assembled into systems furniture in the warehouse. Pallet conveyor connects the AS/RS to the warehouse for all input/output.

The four-story warehouse (Figures Yoko.1 and Yoko.2) serves as a storage area for parts and assembled furniture that are constructed there. Sixteen vertical conveyors interface with three Spacehawk systems (600 kg capacity overhead monorail) to deliver raw and finished material throughout the facility. Pallets are bar coded, and all movement is computer controlled.

Okamura makes extensive use of ergonomics and materials handling equipment in the furniture assembly operation. A robotic depalletizer unloads pallets of drawer systems for desks that are fed into a rotary rack for temporary storage. These drawer parts are retrieved and sent to the assembly line when needed.

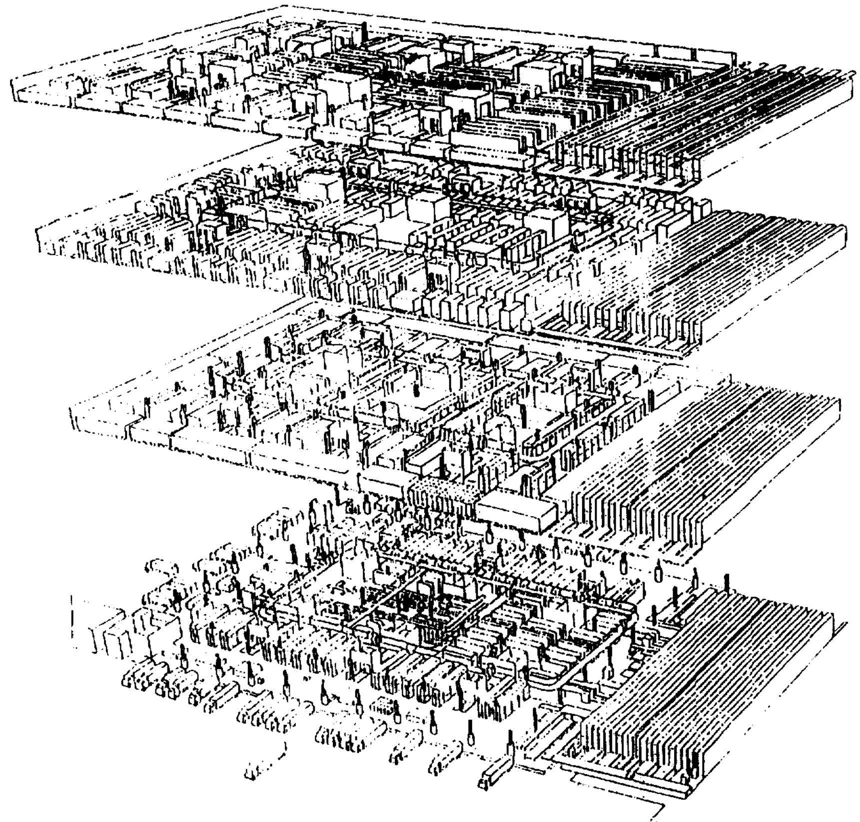


Figure Yoko.1. Facility Layout

YOKOHAMA DISTRIBUTION CENTER

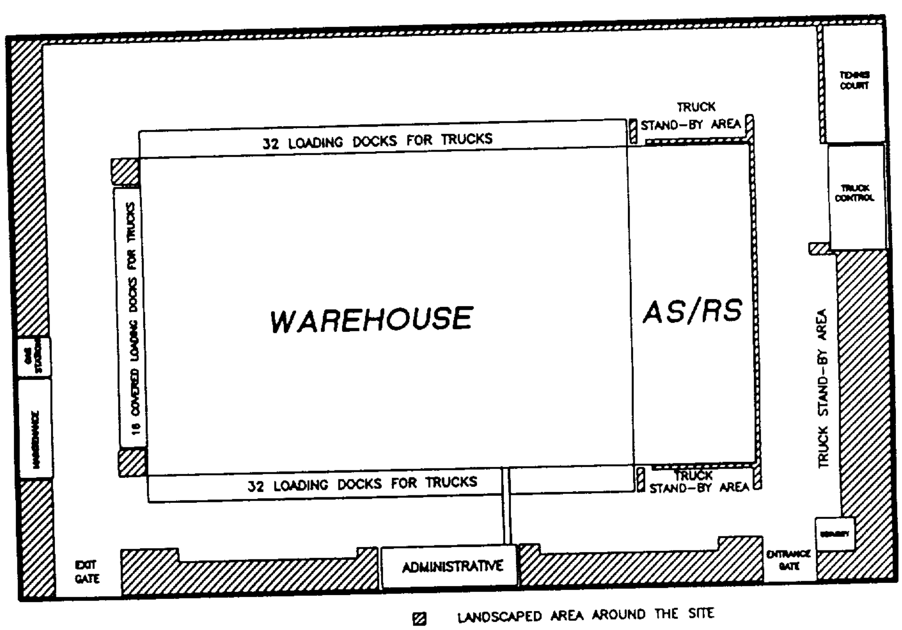


Figure Yoko.2. Floorplan

Information concerning the type and number of desk sets to be assembled is input to the control system, and components are retrieved and fed to a depack work station, where operators use vacuum-assist devices to hold the components as they remove the cardboard and plastic packaging. Drawer components are conveyed to an assembly area where they are attached to desk tops. All of the package conveyor in this area consists of XenoRol line shaft driven rollers manufactured by Okamura. After the assembly operation is completed, desks are palletized and put into temporary storage until required for shipment.

Table Yoko.1
Automated Warehouse Specifications

Type	Stacking crane (building type)	
Weight Capacity	Avg 300 kg/PL Max 600 kg/PL	
Stock Dimensions (mm)	1,450 W x 1,150 D x 2,250 H (max) " x " x 1,600 H " x " x 1,200 H 1,150 W x 1,500 x 2,250 H " x " x 1,600 H " x " x 1,200 H	
Rack Specifications	Total height 29,920 mm	
	Housing locations	10,192 locations (14 rows x 52 connectors x 14 shelves)
Stacking Crane Specifications	Rated carrying capacity	600 kg/PL
	Running speed	3-105 m/min
	Lifting/lowering speed	5-35 m/min
	Shuttling speed	5-30 m/min
	Number	7
	Electrical specs.	AC 400 V, 30 50 Hz

RESEARCH AND DEVELOPMENT

As a materials handling supplier and integrator, Okamura has built the Yokohama Distribution Facility as a model of computer control and integration of numerous materials handling systems. It is their fundamental policy to support distribution with an accurate knowledge of changing demands and market needs sustained by an order-to-delivery full-service system. Okamura feels that only through the blend of sales, production, and logistics can they provide true customer service.

Table Yoko.2
Rotary Rack Specifications

Stored products: Extension units (for desk parts)	
Use: Automated separation and supply to the assemble line	
Load: Avg 30 kg per tray Max 45 kg per tray	
Dimension of max load (mm):	825 W x 490 D x 709 H (max)
Housing Locations:	216 locations (6 shelves x 36 rows)
Rotation speed: 20 m/min	
Rotation motor: 0.75 kW (inverter)	
Auto-retriever For receiving: For shipping: Lift/lowering speed:	 1 unit (with buffer station) 1 unit (with buffer station) 50 m/min (max)
Location control method: Free location control	
Reception to shipment cycle: Max 240 rotations (Equipment duty value)	

Table Yoko.3
Spacehawk Specifications

Lifting potential		600 kg
Volume carried (mm)		1,450 W x 1,200 D x 2,250 H (max)
Running speed		0-120 m/min (Ave. 60 m/min)
Acceleration/deceleration		Variable (parametric setting)
Drive System	Drive Section	2 D.D. (direct drive) motors Synchronized twin-drive system (patent)
	Hand ring section	Drive roller conveyor system
Transport System	No. of control vehicles	12 per floor
	No. of stations	16 on 2nd and 3rd floors 20 on 1st floor
	Drive and transport communication system	Zone Allocation System (patent pending)
	Station placement communication system	Optical communication system

Table Yoko.4
Conveyor Specifications

Entire Length: About 1,400 m			
Chain Conveyor	Aluminum frame low-noise chain conveyor		
	Speed	12 m/min	
	No. of chain bars	3 bars	2 bars
	Width (mm)	1,450 W	1,200 W
Roller Conveyor	Chain-driven roller conveyor		
	Speed	12 m/min	
	Width mm	1,330 W	
Other Equipment	Automatic lifter (station for space fork)	2	
	Vertical lifter (station for space fork)		Storing: 2 Discharging: 2
	Pallet magazine	2	

GENERAL INFORMATION GIVEN TO PANEL

Facility Size

1) Site area	43,968 m^2 (473,267 sq ft)
2) Building area	22,911 m^2 (246,611 sq ft)
3) Total floor area	77,110 m^2 (830,000 sq ft)

4) Buildings

a. Warehouse building 61,683 m^2 (663,949 sq ft)

- 4-stories high	
- Size (m)	144 (W) x 96 (D) x 31 (H)
- Truck berth	82 vehicles
- Elevator	6 units
- Vertical Conveyor	16 units
- Space hawk	36 units

b. Automatic Warehouse Bldg. 12,492 m^2 (134,462 sq ft)

Building type rack	
- Size (m)	36 (W) x 96 (D) x 31 (H)
- Stacker crane (600 kg)	7 units
- Locations	10,192 L/C

c. Control Office Bldg. 2,149 m^2 (23,131 sq ft)

- 5-stories high

d. Others 786 m^2 (8,460 sq ft)

Table Yoko.5
Throughput
Unit: Thousand yen

	Sep./'91	Oct.	Nov.	Dec.	Jan./'92	Feb.	Mar. *
Receiving	628,877	769,519	1,163,655	1,282,672	1,416,152	1,602,870	1,864,221
Shipment	711,278	1,072,292	1.081,634	1,177,811	1,080,495	1,621,779	2,881,547
Stock	2,846,289	2,543,516	2,625,537	2,730,398	3,066,055	3,047,146	2,029,820

* Estimated Values

	Apr./'92	May	June	July	Aug.	Sept.	1/2 TOTAL
Receiving	2,300,000	2,050,000	2,300,000	2,230,000	1,700,000	1,900,000	12,480,000
Shipment	2,200,000	1,850,000	2,300,000	2,230,000	1,700,000	1,900,000	12,180,000
Stock	2,800,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	

	Oct./'92	Nov.	Dec.	Jan./'93	Feb.	Mar.	TOTAL
Receiving	1,770,000	2,000,009	2,000,000	1,450,000	2,550,000	2,600,000	12,370,000
Shipment	1,770,000	2,000,000	1,900,000	1,450,000	2,450,000	3,100,000	12,670,000
Stock	3,000,000	3,000,000	3,100,000	3,200,000	3,200,000	2,700,000	

Share of Shipment Categories in Fiscal Year 1991

Shipment to local service points:	3,492,746 cubic ft (51.9%)
Direct shipment to customers:	3,235,305 cubic ft (48.1%)
Total	6,728,051 cubic ft

Direct Shipment to Customers

In Tokyo, Kanagawa, Yamanashi, Niigata and Okinawa districts

Shipment to Local Service Points

To nine service points: Sapporo, Sendai, North Kanto, Kashiwa, Shizuoka, Nagoya, Osaka, Hiroshima, and Fukuoka

Planned Share of Shipment Categories

Direct shipment to customers:	53.2%
Shipment to local service points:	46.8%

Table Yoko.6
Storage Capacity -- Number of Storage Pallets

4F	Rack	3,571	PL (= L/C)	AS/RS 10,192 PL (=LC)
	Floor	6,360	PL (322 L/C)	
3F	Rack	3,722	PL (= L/C)	
	Floor	4,354	PL (252 L/C)	
2F	Rack	1,737	PL (= L/C)	
	Floor	8,508	PL (484 L/C)	
1F	Rack	1,453	PL (= L/C)	
	Floor	240	PL (20 L/C)	

Storage Pallets		Storage Locations	
Rack	10,483 PL	Rack	10,483 L/C
Floor	19,462 PL	Floor	1,078 L/C
+ AS/RS	10,192 PL	+ AS/RS	10,192 L/C
Total	40,137 PL	Total	21,753 L/C

Table Yoko.7
Storage Capacity--Storage Space on Each Floor

	AS/RS	1F	2F	3F	4F	Total
Storage Space (Floor) (Rack)	 0 10,792	 0 1,306	 4,387 955	 2,400 1,988	 3,522 1,545	 10,309 16,586
Aisle space	1,700	11,249	7,475	8,388	7,965	36,777
Assembly space	0	1,224	0	256	0	1,480
Pit space	0	2,496	0	0	0	2,496
Dead space	0	2,339	1,490	1,275	1,275	6,527
Total	12,492	18,762	14,307	14,307	14,307	74,175

Table Yoko.8
Investment

Item	Amount in ¥Millions	Share
Building construction cost	10,645	71.4%
Warehouse building	9,717	
Automatic warehouse building	928	
Introduction costs	3,165	21.2%
Automatic warehouse equipment	1,510	
Conveyors	739	
Storage facility	76	
Assembly facility	311	
Construction	325	
Associated facility	204	
EDP facility	621	4.2%
EDP equipment	553	
Equipment works	68	
Software development costs	478	3.2%
Area host (IBM9121)	389	
Control (IBMS/88)	89	
Total Investment	14,909	100.0%

Table Yoko.9
Truck/Shipment Throughput

Average truck unloading time: 82.0 min Average truck loading time: 119.9 min Number of arrived trucks (monthly): 1,228 Number of departed trucks (monthly): 3,323 Number of arrived trucks (daily): 51.2 Number of departed trucks (daily): 138.5	Number of shipment orders (daily average) Direct shipment to customers: 425.9 Shipment to local service points: 44.3 Number of shipment orders (monthly average) Direct shipment to customers: 10,222 Shipment to local service points: 1,062

Table Yoko.10
Throughput

Date	No. of arrived trucks	No. of departed trucks	Truck Work Time		No. of Shipment Orders	
			Unloading (min)	Loading (min)	Direct shipment to customers	Shipment to local service points
Mar. 2nd	52	89	67	87	262	37
Mar. 3rd	54	93	68	109	285	55
Mar. 4th	45	91	63	113	293	39
Mar. 5th	61	100	74	140	372	38
Mar. 6th	51	151	75	84	428	42
Mar. 9th	61	103	68	144	339	49
Mar. 10th	55	99	71	135	335	51
Mar. 11th	54	104	59	96	368	35
Mar. 12th	68	123	79	148	392	39
Mar. 13th	63	114	72	95	144	53
Mar. 14th	58	158	83	125	500	52
Mar. 16th	63	124	86	128	357	67
Mar. 17th	62	135	89	141	430	75
Mar. 18th	53	151	81	138	556	32
Mar. 19th	37	167	109	99	289	32
Mar. 21st	45	204	93	124	707	48
Mar. 23rd	41	128	72	97	452	40
Mar. 24th	60	163	90	132	512	59
Mar. 25th	49	170	94	121	552	41
Mar. 26th	55	197	105	149	609	34
Mar. 27th	44	152	104	100	249	33
Mar. 28th	48	234	102	132	933	25
Mar. 30th	24	159	82	120	515	47
Mar. 31st	25	114	82	120	344	44

Annual Number of Persons-Hours Worked

Experience is shown below in total annual work hours. (The experience in ten months from June 1991 to March 1992 was converted into annual values.)

Table Yoko.11
Annual Persons-Hours Worked

(Object : YDC employees)

Classification	Persons	Work hours/year
Manager	8	2,040 hours/person
Supervisor	19	2,402 hours/person
Worker	47	2,230 hours/person
TOTAL	**74**	**2,254 hours/person**

Table Yoko.12
Number of Items Stored

Plant Name	Product	Stock	Retention
Oppama Plant	Chair and table	1,144	1,144
KOK	Desk	993	1,081
KOK	Storage cabinet	503	503
Tsukuba Plant	Storage cabinet	308	440
Purchasing	Cabinet and locker	352	308
TOTAL		**3,300**	**3,476**

Table Yoko.13
Productivity Measures

Control Item	Set Value	Result	Achievement
Receiving indexes - No. of arrived trucks per day	83 trucks	51 trucks	61.4%
- Warehouse amount (cubic feet per day)	90,100 cubic feet	46,309 cubic feet	51.4%
- No. of warehouse pallets per day	1,392 PL	1,157 PL	83.1%
- Loaded amount (cubic feet) per pallet	70 cubic feet	40 cubic feet	57.1%
- Unloading time per truck (11 T)	90 minutes	82 minutes	109.8%
Shipment indexes - No. of departed trucks per day	148 trucks	139 trucks	93.9%
- Shipped amt. (cubic feet per day)	96,000 cubic feet	78,682 cubic feet	82.0%
- No. of shipped pallets per day	3,038 PL	3,228 PL	106.3%
- Loaded amt. (cubic feet) per pallet	32 cubic feet	24 cubic feet	75.0%
- Loading time per 4-ton truck	60 minutes	120 minutes	50.%
Picking indexes - Picking time (including transportation time)	2.5 minutes/truck (24 trucks/hour)	3.5 minutes/truck (17 trucks/hour)	71.4%
Receiving/shipment control indexes - Work hours per day	8.0 hours/day	9.2 hours/day	87.0%
- Work force per forklift truck	35 persons	38 persons	92.1%

Accuracy Measures

1) Inventory levels (recent experience of stock-taking as of January 1992)

o	Amount of stock:	3,047,476	thousand yen	(A)
o	Difference (Plus side)	6,454	thousand yen	
	(Minus side)	-9,670	thousand yen	
	Total difference	16,124	thousand yen	(B)
	Net difference	-3,216	thousand yen	(C)
o	Absolute difference ratio	0.52%		(B)/(A)
o	Net difference ratio	0.10%		(C)/(A)
o	No. of storage locations undergoing stock-taking (automatic warehousing not included)	10,198	L/C	(D)
o	Difference in no. of locations	132	L/C	(E)
o	Location unmatch ratio	1.294%		(E)/(D)

2) Shipping (Recent experience as of March 1992)

o	No. of pickings for shipment	77,481
o	No. of missing or wrong shipments	81
o	Missing/wrong shipment ratio	0.105%

Site: **Sun Distribution Center**
Nagasakiya, Shin-Narashino
c/o 3-7-8 Akanehama Narashino
Chiba 275, Japan

Date: April 7, 1992

Report Author: T. C. Day

ATTENDEES

JTEC:

T. Day
E. Frazelle
J. Apple
G. Petrina
C. Uyehara

HOSTS:

Jun Suzuki — President, Nagasakiya

BACKGROUND

The Sun Distribution Center is a new facility that opened only one month before the panel visited. The company was founded in 1974 and distributes dry goods to 350 stores in the region. Each store is serviced once per week.

The exceptionally smooth start-up of this new facility was facilitated by a requirement that there be no changes in control software in connection with the move. The center handles 2,000,000 cases per year -- about 8,000 cases per day with an average of 20 items per case.

Two hundred people are employed at the center. Of these, 20 percent are full time (7 1/2 hrs/day) and 80 percent are part-time (less than 6 hrs/day).

Total floor space for the facility is about 200,000 square feet, including all mezzanine structures. The company uses a unit of area measure called a "Tsubo," which is the area taken up by three tatami mats, or about 36 square feet.

The company does not own inventory, but distributes it to stores for a commission totalling about 4 percent of wholesale cost.

MATERIAL FLOW AND TECHNOLOGY EMPLOYED

Each of the stores serviced by this distribution center places its replenishment orders using a Monarch NW7 bar code system. Orders are selected from flow racks using light-directed picking into a tote box.

Picked merchandise is sorted on a six-year-old Logan tilt tray sorter into 400 pack stations. Packed orders are sorted into truck staging lanes via a sliding shoe sorter.

ADDITIONAL OBSERVATIONS

In the discussions following the tour, the panel learned that facility rental space for this location (about one hour outside of Tokyo) is about three times the cost of similar space in the United States. Management at the facility reiterated a common theme that land cost and a labor shortage are the principal drivers for investment in material handling equipment.

Management commented that by the year 2020 over 25 percent of Japan's population will be over 65 years of age. As a result, working conditions, adapting the work place to the needs of older workers (large clear signs, minimum walking, improved lighting, etc.), and improved ergonomics are high priorities in facility design. Sweden was suggested for ergonomic benchmarking.

Both at this facility and others visited, the labor shortage is really a shortage of people who are willing to work in the warehouse environment rather than an absolute shortage. Despite all the efforts to improve working conditions, it is still an issue for even the best of the facilities observed -- leading one to conclude that there may be a cultural bias against this type of work that makes it difficult to compete for available workers.

Site: **Nichi-Rei (Funabashi)**
Nichirei Corp.
Hinode 2-19-3
Funabashi-shi
Chiba 273, Japan

Date: April 9, 1992

Report Author: T. C. Day

ATTENDEES

JTEC:

T. Day
E. Frazelle
J. Apple
G. Petrina
C. Uyehara

HOSTS:

Toshihide Nire — Manager, Funabashi #2 Logistics Service Ctr.

BACKGROUND

The Funabashi Logistics Service Center is the largest frozen food storage and distribution center in Japan. Located in a six-story facility, the company stores 8,000 SKUs and handles 25,000 tons of product per month. This translates into 4,400 cases per hour.

The employment complement consists of 80 production workers and 30 clerical/administrative persons. Seventy percent of the orders are shipped on the day of receipt, with the remainder shipped the next day.

The food industry in Japan reportedly is run on the same very tight margins that it operates on in the United States.

MATERIAL FLOW AND TECHNOLOGY EMPLOYED

The high cost of land led Funabashi to focus on storage density in planning the facility. As a result the company used pallet frames, lift trucks, and block stacking of pallets in the freezer rooms.

Two main freezer rooms are maintained at -25°C and -40°C respectively. The staging area for these rooms is maintained at +10°C, and the shipment sorting area at +20°C. The company employs 60 lift trucks to move stock around.

ADDITIONAL OBSERVATIONS

All the lift truck drivers are provided under a contract with a third party. This contractor arranges for training and assures competency. Most other labor in the facility is daily casual labor provided by an agency at the rate of ¥15,000 per day per worker.

Received cases are already bar-coded by the supplier, but all palletization and sortation efforts on received cases are manual.

Site: **Shin Tokyo Post Office and Tokyo Parcel Post 4.23 Shin-sura 2 Koto-ko Tokyo 137, Japan**

Date Visited: April 7, 1992

Report Author: J. M. Apple, Jr.

ATTENDEES

JTEC:

J. Apple
T. Day
G. Petrina
C. Uyehara

HOSTS:

Katsunori Hata — Coordinating Section

BACKGROUND

The Shin Tokyo Post Office opened in August 1990 with an operating plan and capacity to meet growth projections through the 1990s. The facility houses two relatively independent operations: 1) letters and small flat parcels, and 2) parcel post packages. This facility handles about one-third of all of Japan's intercity mail. Current average volume requires about 60 percent of the facility's capacity, but holiday peaks of nearly 50 percent over normal activity in July/August and November/December require the use of an off-site facility for some parcel handling.

The facility operates 24 hours a day, 365 days per year. Heavy receiving is scheduled at night, with most of the sorting done during the day.

In order to locate the post office centrally for the greater Tokyo service area, it is situated on very expensive real estate -- and like many Japanese facilities, has multiple stories. The first and second floors, which house the post office operations, are each about 82,000 m sq (900,000 sq ft). The third floor, which houses parcel post operations, is slightly smaller, as that level includes a full set of truck docks on each side, accessed by ramps from the street level.

MATERIAL FLOW AND TECHNOLOGY

To facilitate flow and mechanical handling throughout the system, all mail in the post office operation is handled in stackable, but not nestable plastic tote boxes (approximately 12" x 20" x 12" high). Sixteen totes are carried in a specially designed cart. In the parcel post operation on the third floor, packages are stacked loose in the same carts. Mail is pre-sorted prior to arrival at the Shin Tokyo P.O. so that each tote contains only one of three mail types: loose large flat pieces, bundles of letter-size mail, and large first-class items.

As incoming trucks arrive at the facility, they are driven past a remote dispatching terminal that interrogates a coded tag and automatically assigns them to one of 100 docks at ground level or one of nearly 100 at the third level parcel post operation.

According to a work processing schedule, totes from carts are automatically unloaded in special destacking devices and conveyed to the appropriate work area, or entire carts may be moved by elevator and a simple automated guided vehicle system both to and from processing areas. Several types of sortation systems are used for the various mail sizes and sort requirements. Individual letters and large flats are read automatically through very high speed optical character recognition readers and sorters. Resulting bundles may be resorted at one of two tilt tray sorters. Bundles and flats are eventually returned to totes, now with a single outlying P.O. destination. Pre-printed bar code tags are inserted in special slots in the totes, which are in turn sorted on a high speed pop-up wheel sorter. Larger outlying P.O. operations have dedicated tote accumulation lanes, while smaller ones may be mixed in a single lane. When a dedicated P.O. lane has sixteen totes in queue, the lane is emptied and totes descend via spiral chute to special cart-loading devices on the first floor.

For smaller post offices, five carts are positioned along a small, fast AS/RS machine that sorts and loads totes directly into the carts. Carts are stacked and loaded manually into outbound trucks based on the predetermined dispatch schedules that appear on large electronic displays along the shipping docks.

In the parcel post operation, packages are transferred manually from the carts to large belt conveyors that carry the packages to elevated induction stations to four (4) tilt-tray sorters. Sorted parcels are restacked manually in the carts.

SUMMARY

It is clear that human factors were a very important consideration in the design of the facility. Bright coordinating colors are used throughout the building, and there is a much greater sense of spaciousness here than in any other facility that the JTEC panel visited.

The mail sorting processes themselves are not so different from those used in the United States, but the replacement of traditional mailbags with plastic tote boxes permits the mechanization of much of the handling and makes the remaining manual handling easier. The most unique mechanization in the system is the automated unloading and loading of totes in the mail carts. A particularly unusual application is the small AS/RS for sorting and loading totes bound for smaller post offices. It is the equivalent of a forty-position, double-deep micro-load system -- much too small to be justified by the approach normally taken in the United States. However, the number of handling units must be significantly higher and the load density for transportation much lower.

Engineers from the Ministry of Posts and Telecommunications did the basic design work for the material handling system and employed standard equipment offerings from a variety of suppliers. The most integrated portion of the system is tray conveying and sorting, and was provided by Toyo Kanetsu. Tilt tray sorters were provided by Tsubakimoto, Hitachi, and NEC (a Kosan machine). The guided vehicle was provided by Shinko Electric.

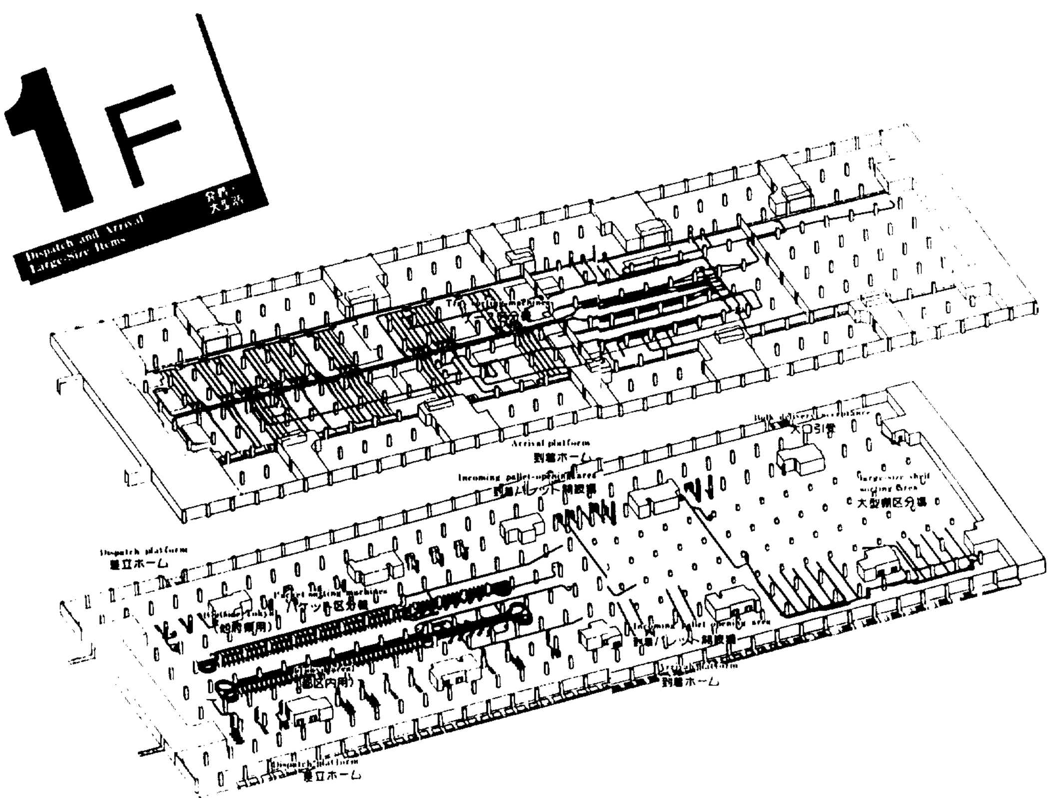


Figure Post.1. First Floor Layout

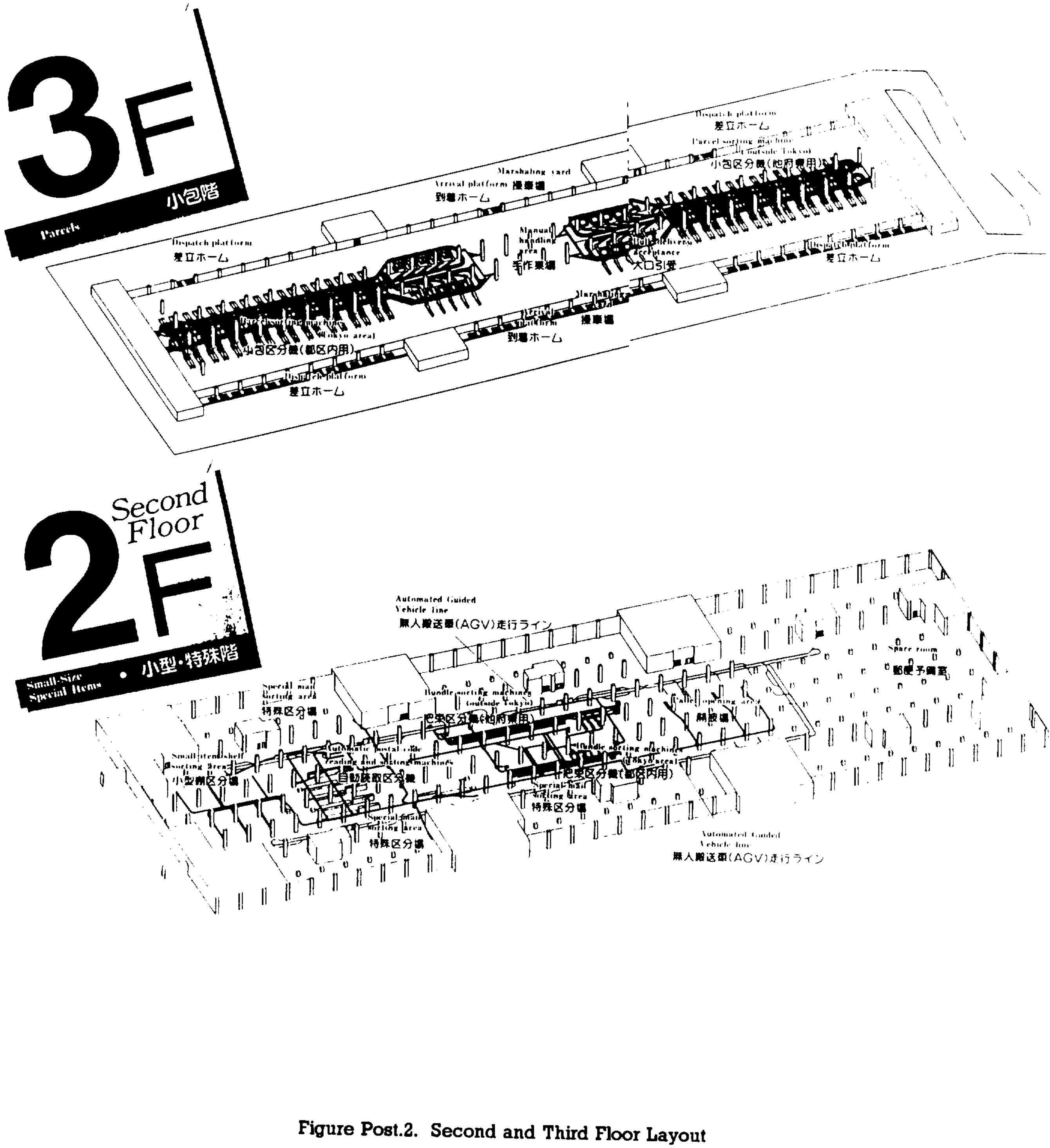


Figure Post.2. Second and Third Floor Layout

Site: Chiba Toyopet
Colnet Facility
3-35 Akanehama
Narashio-shi
Chiba 275, Japan

Date Visited: April 9, 1992

Report Author: J. M. Apple, Jr.

ATTENDEES

JTEC:

J. Apple
T. Day
E. Frazelle
G. Petrina
C. Uyehara

HOSTS:

Noboru Takeshita Planning Division, Production Control

BACKGROUND

Katsumata is one of several car dealers groups which has a sales contract with Toyota Motor Corporation, and includes several automobile dealer organizations. Chiba Toyopet is one of those organizations and serves Chiba prefecture. Colnet is a distribution center that processes new vehicles prior to being delivered to group dealers.

Cars to fill customer and dealer orders are staged near Nagoya. Each day about 600 are transported by a dedicated ferry to the Colnet facility. Forty percent of those are ready for immediate distribution to the field. The remaining 60 percent will receive final inspection and the installation of some options and accessories at this facility. They include air conditioning, air purifiers, selected trim, sound systems, telephones, floor mats and seat covers.

MATERIAL FLOW AND TECHNOLOGY

Vehicles requiring processing are stored in an 11-aisle AS/RS. The input/output system is a cart-on-track system (with spinning tube drive). Drivers position vehicles on large metal pans at one of several load stations. The pans are transferred onto the carts and then off the carts at the assigned aisle of the storage system. The system has a response time of about five minutes to retrieve a vehicle and has a total capacity of more than 2,000 transactions/day. A vehicle may be in and out of the system two or three times before it is complete. Although AS/RS storage of vehicles is not unknown in the U.S., the use of a cart-on-track loop for front-end handling seems unique and effective.

From the inventory of available vehicles and based on delivery priorities, daily work schedules are developed. Parts and materials for each day's work are delivered in bulk on the day before. The parts are manually sorted and kitted for each vehicle and stored in a mini-load AS/RS in fiberboard containers.

After a vehicle is withdrawn from the storage system, its kit is requested and it is delivered to the appropriate work station on an electrified monorail system. The carrier is loaded automatically at the mini-load and unloads automatically onto a lift platform that lowers the load to floor level.

There are three AEM loops at floor level with large carriers for moving the vehicles through the air conditioning assembly process.

The entire system was designed and installed by IHI and a service division of IHI has an ongoing maintenance contract. To insure continuous uptime, several operators are assigned to Colnet for maintenance.

SUMMARY

The design philosophy for this facility was to eliminate difficult or dangerous work for employees, to maintain a high level of cleanliness, to provide damage-free movement and storage of automobiles and to provide a bright and open environment for employees to perform high quality work. Although the panel may not have found hard justification for the extent of automation provided here, it supports the design philosophy very well, and serves as a constant reminder to employees and visitors of what the mission and expectations are.

APPENDIX D. TRIP REPORTS (JAPAN LOGISTICS TOUR '92)*

Site: **Japanese Council of Logistics Management**

Date Visited: Monday, February 3, 1993

HOSTS:

Motoki Inatsuka
Secretary General
Japanese Council of Logistics Management

Ippei Yamano
Deputy Manager
Japanese Council of Logistics Management

Jun Suzuki
President
Sun Bird Franchise Logistics Center

The Japanese Council of Logistics Management is similar in mission to the U.S. Council of Logistics Management. It is the most prominent professional society for Japanese logistics professionals, with 300 corporate members and 120 individual members. Every other year JCLM sponsors Logis-Tech Tokyo, a trade show and conference featuring material handling and distribution technology. JCLM also assembles key statistics describing the sales and application of distribution technology in Japan.

Visit Summary

Motoki Inatsuka began by describing the history and current trends in Japanese logistics.

Thirty years ago the Japanese had no formal concept of logistics as we know it today. With the growth of the Japanese economy in the 1970s, Japanese was forced to organize a means of linking its high rates of production with high rates of consumption. This was the birth of large-scale physical distribution in Japan. It gave birth to the need for mechanization and in-house corporate logistics functions.

* excerpted by permission of Edward Frazelle from "Japanese Logistics Discovery Tour 1992"

The 1980s were also characterized by high economic growth rates. In addition, the 1980s brought SKU proliferation (a 37.5 percent increase in the number of SKUs from 1987 to 1989), a renewed emphasis on quality, and just-in-time deliveries. Severely overcrowded transportation routes and limited retail space placed an even greater emphasis on the logistics function in Japan.

The 1990s bring even greater challenges for Japanese logistics managers. Globalization, continued SKU proliferation and JIT deliveries place increasing demands on logistics operations. At the same time, an aging society and demands for reduced working hours make the acquisition of additional labor difficult. This labor shortage, coupled with a fascination with technology help explain the high levels of automation seen in Japanese logistics operations. According to Inatsuka, the Japanese are looking for the New Silk Road, that is, logistics to improve the quality of life.

Questions and Answers

Q. In a typical Japanese company, how high in the management structure is the logistics function?

A. *The chief logistician is moving up from a middle- or high-level manager to an executive position.*

Q. What are the Japanese considering to overcome the traffic congestion problems?

A. a. *Dedicated cargo handling lanes on major highways.*
b. *Special load/unload terminals located on medians.*
c. *Underground transport like the Channel Tunnel.*

Q. How much are full-time and part-time warehouse workers paid?

A. a. *Part-time: ¥700/hr = $5.60/hr*
b. *Full-time: ¥4,000,000/yr = $32,000/yr*

Q. Are manufacturing and warehouse workers paid the same?

A. *Yes, except for highly-skilled manufacturing jobs.*

Suzuki indicated that many working hours go unreported because the workers enjoy their work.

Jun Suzuki then provided a detailed comparison of logistics operations in Japan and the United States. Suzuki is the president of Sun Shonin Franchise Logistics Center, Nagasakia's logistics subsidiary. He is also the leading logistics consultant in Japan and perhaps in the world. His first visit to the U.S. was in 1973.

A list of quantitative comparisons (as prepared by the Japanese) of the conditions affecting logistics operations in the U.S. and Japan is shown in Table D.1.

Table D.1

Attribute	Japan	U.S.	Ratio
Population	121,000,000	227,000,000	1.87
Country Size (Square Km.)	0.37	9.37	25
Accuracy Goal	1/10,000	1/1,000	10
Population Density (People/Km^2)	329	26	12
Unemployment	2%	7%	3.5
Presidents' Salary	$200,000	$3,200,000	16
Annual Working Hours	2,159	1,957	1.1
Retail Outlets	1,630,000	1,600,000	1.0
People per Retail Outlet	74	142	2
Wholesaler Sales/ Retailer Sales	2.2	1	2.2

Other Notes

- Transportation workers work an average of 2,600 hours per year.
- There has been rapid growth in POS terminals.
- There has been a rapid growth in automation, including AS/RS, sorters, AGVs and light-aided picking. AS/RS sales doubled from 1987 to 1989.
- There are 5.5 million vending machines for hot and cold beverages in Japan. Many serve both temperatures.

Site: **Sapporo Beer, Chiba Brewery**

Date Visited: Monday, February 3, 1992

HOST: Hiroshi Saito, General Manager
Logistics Department

Sapporo was established in 1949 and now holds the second largest beverage market share in Japan. With annual sales of ¥513 billion ($3.8 billion at $135), Sapporo's product line includes beer (688 products), soft drinks (295 products), imported wine and brandy (310 products), domestic wine and brandy (1,849 products), and advertising items (1,425 products). Sapporo operates 10 large distribution centers in Japan and employs over 4,000 people.

Chiba Brewery

Sapporo's Chiba Brewery was completed in May 1988, and produces 12 of Sapporo's beer products (bottles, cans, and kegs). By outbound volume, 28 percent of the product goes to other breweries (11-ton trucks), 24 percent to branch offices (11-ton trucks), 33 percent to sales agents (via 6- to 11-ton trucks), and 15 percent direct to retail outlets (via 2-ton trucks). Overall, 57 percent of the outbound trailers are 11-ton vehicles; 13 percent, 8-ton vehicles; 6 percent, 6-ton vehicles; and 24 percent, 2-ton vehicles.

Design Team

The distribution center was designed by a team of five logistics engineers from Sapporo. Hitachi was chosen from three vendors as the prime contractor.

Investment Cost

The total brewery cost approximately ¥65 billion ($520 million at ¥125/$); ¥15 billion ($120 million) for land, and ¥50 billion ($400 million) for building and equipment. An article on Sapporo estimated that 64 percent of the building and equipment, ¥32 billion ($256 million), went to machinery and automation. Our hosts estimated that 20 percent of the total machinery and automation cost, ¥6.4 billion ($51.2 million), was tied up in the distribution center.

Staffing

The total brewery staff consists of 130 people. Of those, 90 are brewery operators and 40 are managers and office workers. Approximately 10 people work in the distribution center; there are 4 lift-truck operators, 4 drivers, and 2 maintenance technicians.

Automated Storage/Retrieval System

A 10-aisle AS/RS (Hitachi) housing 25,100 pallets (5.5 days) is the material handling highlight of the facility. Each aisle is equipped with two, twin-shuttle S/R machines. Each machine operates at a maximum speed of 480 feet per minute. Each end of the system is serviced by a two-level, cart-on-track conveyor (SI Handling) operating at 225 feet per minute. Each of the 75 carriers can accommodate two pallets.

The average out-and-back cycle time is 95 seconds, or approximately 25 seconds per pallet. Thus, the throughput capacity per S/R machine is 144 transactions per hour. With 20 S/R machines, the overall system capacity is nearly 3,000 pallets per hour.

Automated Trailer Loading

Two automated trailer loaders are used for side loading outbound trailers. Each loader is equipped with nine sets of two-deep forks. The loaders are fed with pallet conveyor.

At 2.5 minutes per trailer, each automated loader has a capacity of 24 trucks or 432 pallets per hour.

Productivity

The overall brewery productivity is reported to be 14,600 HL per person per year. The maximum productivity in the DC is 100 outbound pallets per hour, and 190 overall transactions per hour. (This assumes 6 warehouse operators working 8 hours per day.) Assuming straight-line depreciation for 7 years and an hourly wage of $15, the total storage and handling cost per outbound pallet is $5.45, that is, $5.30 investment per pallet and $0.15 labor cost per outbound pallet. The total storage and handling cost per transaction is $2.25 per transaction.

Smart Card Trailer Scheduling

Upon check-in, each driver is issued a smart cart for scheduling his route through the brewery site. The smart card is used to track and identify the trailer throughout its stay on the brewery site. Once dispatched to the automated loading operation, the driver uses the smart card to release and record the outbound load. Each trailer is on-site for approximately 15 minutes.

Plastic Pallets

Currently, 50 percent of the pallets used in the DC are plastic. The plastic pallets are more durable, eliminate crushing, and are more attractive than wooden pallets. Sapporo is moving rapidly to 100 percent plastic pallets.

Site: **Fukaya Distribution Center**

Date Visited: Tuesday, February 4, 1992

HOSTS: Yasuo Shigeta
Physical Distribution Division Manager

Shigeru Kurosawa
President, Fukaya Distribution Center

Suzukiisms: According to Suzuki

1. Creativity is the U.S. advantage. Application is the Japanese advantage.

2. The privatization of the national railroad has helped rail service dramatically. The new express service between Tokyo and Osaka will reduce the travel time from 3 hours to 2.5 hours, virtually eliminating domestic air travel on that route.

3. Arrogance, evolving from its tenure in world dominance, is the major reason for U.S. decline. Suzuki believes it is a natural cycle. He is disappointed that members of the Japanese Diet are beginning to show signs of arrogance.

4. The Japanese measure annual improvement of overall operations and do not focus on the productivity of individual logistics activities. Suzuki made the analogy of measuring the batting averages of individual baseball players as opposed to the team's winning percentage.

5. Suzuki brought along videos of several Japanese logistics operations including his Sun Shonin DC and the Nippon Shupan book distribution center.

Shiseido

With over ¥517 billion ($4 billion) in annual sales and 20,000 employees, Shiseido is Japan's leading cosmetics company. The company was founded in 1927 and is headquartered in the Ginza district of Tokyo. A product line of over 5,000 items is designed to cover all the major consumer profiles. The company is faced logistics challenges stemming from individualized consumption patterns and a break from conformity and materialism.

Logistics Network

4 manufacturing operations
2 hub distribution centers
9 regional distribution centers
15 wholesalers
108 sales offices
25,000 retail outlets

Fukaya Hub Distribution Center

The 180,000 square foot Fukaya logistics center opened in February 1991 with the theme, "Humans and Systems in Harmony." The center is designed with an office-like atmosphere, including color-coordinated buildings and machinery. In serving 7,300 retail outlets, the facility represents 13 percent of Shiseido's annual sales.

Staffing

The facility is staffed with 23 full-time operators and 65 part-time employees, each working an average of 25 hours per week. Assuming 50 weeks per year and 2,100 hours per year for full-time workers, the annual working hours in the facility are 129,550.

Investment

Building:	¥3 billion ($24 million = $133/ft^2)
Equipment:	¥2.5 billion ($20 million = $123/ft^2)

Depalletizer for Incoming Pallets

An automated depalletizer is used to singulate totes from inbound incoming pallets. Individual totes are fed directly via roller conveyor to the micro-load AS/RS for storage.

Unit Load Automated Storage/Retrieval System

A conventional AS/RS is used for pallet storage/retrieval. The storage capacity is 2,320 pallets.

Micro-load AS/RS

The tote storage and handling system is unique in that a shuttle car is provided for every three levels of tote storage. A large mast/elevator services each aisle to transfer totes to/from delivery/takeaway conveyor lines. The storage capacity of the system is 29,000 totes. The throughput capacity is 2,500 totes per hour.

Cross-Belt Sorter

Five waves per day, each lasting forty minutes, are used to govern the flow of totes to induction points for a cross-belt sorter. At induction, the number of units to remove from each tote is displayed on an LED. Induction operators count the correct number of units and orient each unit to be scanned onto the sorter system. The sorting system is equipped with 528 outbound lanes.

Packaging

Pre-inflated plastic fillers are used to fill the outbound totes.

Collapsible, Stackable Totes

Collapsible totes are used to improve space utilization throughout the material handling system. The totes can be collapsed or resurrected in one to two seconds each.

Productivity

On average 30,000 lines, 36,000 cases, and 80,000 pieces are shipped from the center each day. The operating productivity is as follows: 60 lines per hour, 76 cases per hour, and 170 pieces per hour. Recall that, as of the time of our visit, the facility had only been in operation for seven months. The managers expect to be able to double the output of the facility without increasing staffing levels.

Assuming a seven-year straight-line depreciation, the capital cost per line shipped is $0.38. Assuming wage rates of $15 per hour for full-time employees and $6.50 per hour for part-time workers, the labor cost per line shipped comes to $0.15. The total labor and capital cost per line is $0.53.

Accuracy

There were no errors reported in the month of December. The average error rate is 2 in 100,000 shipments.

Site: **Daifuku, Komaki Plant**

Date Visited: Wednesday, February 5, 1992

HOSTS: Akira Kondou
Manager, Public Relations and Training

Masao Fukui
Senior Chief Engineer, Public Relations and Training

Daifuku was founded in 1937. In early 1992 the company had over 2,700 employees and generated ¥130 billion ($1 billion) in sales in 1991. Sales have doubled since 1987. Daifuku operates offices in the U.S., Canada, Singapore, and Europe.

In 1989 the company held a 23 percent market share of Japanese material handling sales. In 1990 Daifuku installed over 1,600 AS/RS aisles, representing a 50 percent AS/RS market share.

Technical Developments

The company is primarily known for achievements in technical development, ranking 131 out of 1.8 million Japanese companies in total patents. The company ranks 13th in Japanese companies in patents granted per employee.

Market Share Domination

The company is organized by industrial application of its products: (1) automotive, (2) flexible and distribution automation, and (3) clean room operations. According to Masao Fukui, every automobile made in Japan is transported on a Daifuku conveyor at some point in its manufacture. Daifuku also dominates the market for automated material handling and storage systems for clean room applications. Daifuku holds a 75 percent market share of inter-process transport and buffer clean FA systems sold in Japan.

The domination stems from the company's developments in systems that produce minimal air flow turbulence, critical to conserving clean room conditions. The domination is so great that SEMATECH, a consortium of U.S. semiconductor manufacturers, has begun to lobby the U.S. government for support of a U.S. supplier of automated clean room material handling and storage systems.

Aggressive Order Cycle Time and Cost Reductions

The current order cycle time for automated storage/retrieval systems is 1.5 months, down from 4 months 5 years ago. The average installation time is 1 week, down from 1 month 5 years ago. The current goals are to reduce the order cycle time below 1 month. Daifuku has also achieved a price reduction of 50 percent over the last 5 years, and is aiming for an additional 50 percent cost reduction over the next 5 years.

To achieve these time and cost reduction goals, Daifuku is currently switching its manufacturing scheduling from make-to-order to a make-to-forecast mode.

Wide Array of Automated Material Handling Products

The Daifuku product line includes monorails, conveyor systems, special-purpose machinery, automated storage/retrieval systems, automated guided vehicle systems, conveyor systems, clean room material handling systems, carousels, racks and shelving, and control systems.

Daifuku's Komaki Plant

Over half of Daifuku's sales are generated at the Komaki plant. All of Daifuku's clean room systems are manufactured at the Komaki plant in addition to a wide range of conveyor, automated guided vehicle, and automated storage/retrieval systems. A printed circuit board shop is also located on the Komaki complex.

Clean room products include a mobile robot (space carrier), an automated storage/retrieval system (clean stocker), an automated guided vehicle (clean shuttle), and automated monorail (clean way). The clean way system is nearly frictionless, operating with magnetic levitation and powered by linear motor drives.

New products under development at Komaki include:

1. An AS/RS for parking garages. Daifuku estimates a 90-second cycle time for the parking AS/RS. The company estimates a 120-second cycle time for conventional parking systems.

2. A pneumatic gear control for zero-pressure accumulation conveyor. The conveyor system has received awards from MITI for appearance and functionality.

3. New clean room systems. New clean room development is conducted behind closed doors.

Modular Systems

One of the keys to Daifuku's success is the modular nature of the company's systems design. An example is the conveyor system sections that are prewired and are literally plugged together to make a complete conveyor system. The same design philosophy has been extended to automated storage/retrieval systems.

Questions and Answers

Q. What portion of Daifuku sales are computer hardware and software related?
A. *Approximately 30 percent. An affiliated company is responsible for software development and installation.*

Q. What portion of Daifuku sales go to research and development?
A. *Three to five percent at the Komaki plant.*

Site: **Mutow Distribution Center**

Date Visited: Thursday, February 6, 1992

HOSTS: *Kiichi Shirao*
Senior Principal Director

S. Kinoshita
Deputy General Manager, Distribution Systems Division

Mutow is a mail order distributor of ladies apparel. With 1991 sales of ¥63 billion ($500 million), the company has experienced an average 10 percent growth rate since 1967. The company grew out of a women's club uniform manufacturer by including a catalog in one of the uniform shipments.

Orders are received between 8 a.m. and 10 p.m. The orders are evenly divided between phone and mail.

Mutow's Hammamatsu distribution center was designed after visits to Sears and J.C. Penney in the U.S. and Ello in Sweden.

Activity Profile

With nearly 30,000 items, Mutow ships approximately 63,000 units per day on approximately 21,000 orders per day. The average unit value is $35.

Direct Put-away to Storage and Picking Twin-Shuttle AS/RS

All inbound cases are placed directly onto inbound case conveyor, and over 70 percent of the inbound receipts are put-away directly into a 34,000 position AS/RS. Standard carton size (approximately 2' x 3' x 1') cases are unloaded onto a conveyor that feeds an automated storage/retrieval system.

In addition to a storage device, the AS/RS also acts as a forward picking area, holding approximately a three-day supply of inventory. The front face of each rack position is a pick face for manual cart picking. The system is mezzanined so that three picking levels are available in each aisle. A picker is assigned to each picking level.

Batch Picking with Dynamic Stock Location

The AS/RS dynamically positions stock overnight to insure that each forward picking location is adequately stocked and that the most popular items are located near the end of the picking aisle. Picking is executed in waves of 200 orders each.

Cross-Belt Sorter Feeds Mobile Packing Stations

Each unit is polybagged and bar coded. This allows automated sortation via a cross-belt sorter. The sorter is over 600 feet in length and runs at 400 feet per minute. Equipped with 400 packing chutes and 238 carriers, each carrier can hold between one and four kilograms. The overall sorting capacity is 17,000 units per hour.

Investment

The total cost of the facility (building and equipment) was ¥3 billion ($24 million). With 300,000 square feet, the total normalized investment comes to $80 per square foot. Assuming half of the investment went to storage and retrieval systems, the investment in storage and handling systems would be approximately $12 million, $40 per square foot.

Productivity

With 160 part-time employees (six hours per day) and 60 full-time employees (eight hours per day), the total working hours per day is 1,440. At 63,000 units per day, the overall productivity is 44 units per person-hour, more than twice that of L.L. Bean.

Questions and Answers

Q. What is your return percentage?
A. Ten percent.

Q. Does Mutow pay the freight charge?
A. Yes. But, mail order companies are jointly discussing charging the freight charge to the customer. Mutow will not be the first to do so.

Q. If a customer requests expedited shipment, who pays the additional freight charge?
A. Mutow does. The Japanese custom is to expect the customer to return the favor.

Q. Is the product manufactured by Japanese suppliers, or is the manufacturing outsourced to suppliers in Hong Kong, Thailand, China, Sri Lanka, and so forth.

A. *Ninety-four percent of the merchandise is manufactured in Japan (230 vendors). However, the country is beginning to move a large portion of its manufacturing offshore.*

Q. Who does Mutow's transportation?

A. *Yamamato, a transportation contractor.*

Site: **Kao, Iwatsuki Distribution Center**

Date Visited: Friday, February 7, 1992

HOST: *Nobuhiro Tanaka*
Director, Logistics Engineering

Kao is a ¥600 billion ($5 billion) manufacturer of toiletries (80 percent) and cosmetics (20 percent). At approximately ¥5,000 ($40) per case, the total annual Kao output is approximately 125 million cases per year. Kao services over 300,000 retail outlets.

Over the last 20 years, Kao has aggressively acted to bypass wholesalers in its distribution network. In so doing, the company has established a network comprised of 9 large manufacturing operations, 10 large DCs, and 85 small DCs. Large DCs are those with output ranging from 30,000 to 60,000 cases per day. Small DCs range from 1,000 to 30,000 cases per day: A (10,000 to 30 thousand), B (5,000 to 10,000), and C (1,000 to 5,000).

Kao's distribution network has been compressed from a high of 130 DCs. The current goal is 60 DCs. Tanaka-san shared a Japanese rule-of-thumb that a distribution center is needed for every 20 km radii.

Kao currently employs over 12,000 people. The ratio of sales employees to distribution employees to manufacturing employees is 2:1:1. Nobuhiro Tanaka shared an interesting comparison of Japanese and U.S. industry. In Japan two people sell a car for every one person making the car; in the U.S. one person sells the car for every two making it.

Kao currently employs over 3,000 people in distribution related operations. Of those, 1,200 are in a delivery function and 1,800 are in DC operations. The current goal is to reduce the DC operations employment to 1,200.

Iwatsuki Logistics Center

Completed in 1987, the 200,000 square foot Iwatsuki logistics center took over two years to complete. The center services the Kanto area of Japan, representing 30 percent of Japan's population of 121 million. With over 600 items, the center processes an average of 60,000 cases per day, with a 24-hour order cycle time. 20 percent of the outbound cases are delivered directly to retailers (6 percent) or wholesalers (14 percent). Eighty percent of the outbound flow goes to terminals feeding retailers (60 percent) and wholesalers (20 percent).

Integrated Distribution Automation

The most impressive aspect of this logistics center is the level of integration of automated distribution systems. Other than pushing outbound pallets onto trailers, there is no human handling of inbound or outbound cases.

Pallets inbound from manufacturing operations are offloaded from trailers equipped with in-floor roller conveyor. Pallets are rolled off the inbound trailers and onto pallet conveyor for direct loading into the 17-aisle, 100' tall AS/RS. The AS/RS has a storage capacity of 600,000 cases (two weeks) and also serves as a staging system for outbound loads.

Automated Depalletizing and Case Picking

Governed by large order waves, pallets flow out of the AS/RS to automated tier depalletizers, face pickers operating at a rate of 1,000 cases per hour. Individual cases flow from the face picker on carton conveyor to (1) sortation/accumulation lanes to fill outstanding orders, (2) to an automated carton flow rack replenisher for individual case storage, or (3) to a carton flow rack acting as the reserve storage for broken case picking. The full-case portions of each order are filled by the depalletizers or by an AS/RS picking cases from the carton flow rack (500 cases per hour).

Light-Aided Batch Picking for Broken Case Quantities

A progressive assembly (bucket brigade) system is used to fill the broken case portion of each order. In batches of five, empty totes flow on the belt conveyor down a long line of gravity flow racks. An order picker is assigned to work each flow rack bay. As each batch of five totes/orders arrives in front of a flow rack bay, the corresponding flow rack lanes and quantities are successively illuminated on the rack face. After the lane/quantity indicator is illuminated, the position light in front of the corresponding tote is illuminated to direct the pick-to-tote operation. The productivity of the operation is approximately 1,000 pieces or 300 lines per hour. Thanks to light-aided recycling verification of the remaining broken case quantity at the end of each wave, the accuracy is nearly perfect.

The Unit Pallet

The unit pallet is a truck-wide pallet that can accommodate an average of 15 store orders. The cases and totes are loaded directly onto the pallet. Outbound pallets are unitized with a rope net and further secured with a large velcro band. A pallet conveyor system feeds the in-floor conveyor of outbound trailers to complete the loop.

Investment

Including building and equipment cost, the entire 200,000 square foot complex cost ¥6.6 billion ($53 million, $265 per square foot), ¥3.2 billion for the building ($25 million, $125 per square foot), and ¥3.4 billion ($28 million, $140 per square foot) for the storage and handling systems.

Productivity

There are 147 full-time-equivalent workers at the center. At eight hours per day, the overall operating productivity is 51 cases per hour. However, other than 10 maintenance operators and a few loaders/unloaders, the entire work force is devoted to broken case picking. Consequently, the case picking productivity is likely to be in excess of 250 cases per hour.

The World's Ultimate Distribution Center

Facility Interior:	Mutow Colors and Shisheido HVAC
Unloading:	Kao automated trailer unloading
Put-away:	Kao and Sapporo automated put-away
Storage:	Mutow combined storage/picking system
Pallet Picking:	Sapporo double-pallet, cart-on-track conveyor
Case Picking:	Kao tier and automated case picker
Broken Case Picking:	Kao pick-to-light and automated cycle counting
Sortation:	Shiseido and Mutow cross-belt sorter
Containers:	Shiseido collapsible totes
Unitizing:	Kao fishnet and velcro unit pallet wrapping

APPENDIX E. TRIP REPORTS (JAPANESE AUTOMATED S/R/T SYSTEMS, 1990 TOUR)*

The following site reports were prepared in November 1990 by Edward H. Frazelle as a result of a trip to Japan to study Japanese automated storage, retrieval, and transport systems for the National Science Foundation.

Sony Logistics' Tokyo International Distribution Center

Sony Logistics Corporation (SLC) was created in 1962 to provide physical distribution services for Sony. SLC in turn has four subsidiary companies: Sony Air Cargo, Sony Logistics (Singapore), Sony Logistics (Malaysia), and Sony Logistics (Thailand). SLC has annual sales of ¥37 billion, operates approximately 3,000,000 square feet of storage space, and employs 840 people. The company is responsible for the physical distribution of raw material (three facilities) and assembly components (two facilities) at Sony manufacturing sites; consolidating semiconductor shipments (one facility); operating factory storerooms (32 facilities); finished goods warehouses (five facilities) and export warehouses (five facilities); supporting direct sales (16 facilities); and operating 10 other facilities involved in physical distribution. This relatively new network of 74 facilities represents a corporate initiative to streamline distribution and to reduce the number of facilities. Five years ago there were 120 facilities in Sony's distribution. Sony is now planning to cooperate with Panasonic and Sanyo to begin sharing distribution facilities and transportation resources to further reduce the number of facilities in the network and to relieve transportation congestion. Other corporate concerns include the attitude of the upcoming generation of workers, the labor shortage, pressure from retailers to take orders as late as 10 p.m., and the overburdened transportation infrastructure.

SLC's Higashi Ohgijima International Distribution Center was completed in July 1990, and is located 18 miles outside of Tokyo. The $33 million steel, reinforced concrete facility is responsible for export warehousing and is located at Tokyo's largest port. The facility was built to house approximately 2,000 SKUs and to process between 700 and 900 pallet shipments per day. The facility is staffed with 42 full- and part-time employees. The total investment in storage and handling systems was approximately $4 million.

* excerpted by permission of the author from *Automated Storage, Retrieval, and Transport Systems in Japan* (1991, U.S. Department of Commerce, NTIS PB91-180232)

Approximately 300,000 square feet of floor space are provided for storage in the 100-foot tall, five-story building. Four of the five stories are used for pallet storage. Shipping and receiving (18 dock doors) are located on the first floor, and loads are transported between floors on one of five vertical conveyors (capacity is 40 pallet moves per hour). Pallet roller conveyor is used to stage loads outside the vertical conveyors. Twenty-four counterbalance lift trucks are used on the upper floors to move loads to and from floor storage.

On the shipping floor a cart-on-track conveyor (7 carts, 130 pallets per hour) is used to transport loads from off-load lines to one of 12 shipping staging lines (pallet conveyor). All loads are stretch-wrapped at one of four automated stretch-wrapping machines and bar coded for tracking throughout the facility and through latter stages of the distribution network.

Sun Bird Franchise Tokyo Logistics Center

The Sun Bird Franchise Tokyo Logistics Center (TLC) is a terminal warehouse for apparel merchandise. The three-story, 130,000 square foot facility is operated by Sun Shonin Ltd. Sun Shonin is a division of the Nagasakiya Group, one of the largest supermarket companies in Japan.

The TLC houses approximately 3,000 stock-keeping units, ships nearly 3,000 cartons per day and receives approximately 1,500,000 cartons per year from over 100 suppliers. Floor storage to clear heights ranging from 12 to 15 feet is used throughout. The facility is staffed with 35 full-time and 65 part-time employees who average approximately 3,000 working hours per year.

The focal point of the facility is a Logan tilt-tray sorter. The sorter travels at one meter per second, sorts 6,000 units per hour; feeds 400 LED-equipped sort lanes; and carries 400 18-inch trays. Five sorter induction stations are manually fed with cartons by a batch-picking operation. Induction operators open the cartons, retrieve polybagged units from the cartons, apply bar code labels to the polybagged units, and place the units on the sorter.

A 60-foot long Tubaki belt sorter feeding five outbound shipping lanes also operates in the facility. The sorter is rated at 1,800 cartons per hour.

The computing systems on-site include a 335 MB MODCOMP Tri-Dimensional AEG mainframe with CPU (512 MB x 2), Disk (335 MB x 5), 9 printers, and 14 remote terminals. The system controls the automated sortation system and the in-line cubing/weighing system for outbound cartons.

The most unusual aspect of the facility is the creative utilization of limited storage space. First, the facility is almost void of aisle space. Instead, nearly 70 percent of the floor space is covered with in-floor roller conveyor. Second, a mezzanine creates a second level of shipping staging.

In the high turnover facility, the elapsed time from order receipt to merchandise delivery is between three and four days.

Two physical inventory counts are completed each year. Average inventory levels are between 5 percent and 10 percent of ¥17 billion in annual sales.

The owner and manager of the center, Jun Suzuki, is also a physical distribution systems consultant. At the completion of our facility tour Suzuki described several recent consulting engagements. Aspects of some of the most interesting systems are described below:

1. An overhead, self-propelled monorail for automated replenishment of totes to flow rack at Kuraya Pharmaceuticals.

2. A rotary rack carousel used in a health and beauty aids distribution operation (15,000 SKUs) to support order picking at remote, pick-to-light picking stations. The system permits a picking rate of over 250 lines per man-hour and is automatically replenished from a large, automated storage/retrieval system.

3. The Nippon Shuppan book distribution center (15,000 titles) where 1,000,000 replenishment books on 600,000 order lines (25 percent via computer link and 75 percent via mail and telephone) and 800,000 new books on 250 titles are shipped per day. One daily pass is made through the warehouse locations to complete the order picking activity. Order pickers deliver books to one of 24 sorter inductors who feed automatic destackers and an automated sorter induction system. The newly installed, $20 million sortation system is rated at 43,200 books per hour and can sort for 1,500 customers at a time (10 large sort lanes and 150 customers assigned per lane). The system also automatically stacks books coming off the sortation lanes. Sixteen order pickers, 5 material handlers, and 24 sorter inductors are employed at the facility.

4. Kao Soap's automated case picking system. The system is similar in design to automatic item pickers used for automated broken case picking.

Sapporo Beer's Chiba Brewery

Sapporo Beer holds the second largest beer market share in Japan. Sapporo is also aggressively pursuing U.S. sales. Exports to the U.S. doubled between 1984 and 1988.

Sapporo Beer's Chiba brewery is one of the newest and most sophisticated in the world. The facility was completed in June 1988 and has a normalized production capacity of 1.5 million bottles per day. The total number of persons employed on site is 130, many of whom are employed in the visual inspection and monitoring of 4 production lines -- 1 for cans, 1 for kegs, and 2 for bottles. Bottles are filled at a rate of 1,000 units per minute and labelled at a rate of 600 bottles per minute.

Over 300 full trailers are loaded and shipped outbound from the brewery each day. On-site trailer scheduling is automated and is facilitated with magnetic smart cards. A smart card is issued to each driver upon arrival on-site at the brewery. Each driver inserts his smart card into a card reader that communicates a request for the AS/RS to build a corresponding trailer load. Once a request is submitted, the AS/RS requires about 15 minutes to retrieve a complete load. In the meantime, drivers wait near shipping to be dispatched to the semi-automated loading docks.

The single operator, semi-automated loading system is capable of loading eighteen pallets in one move. The system is basically a large lift truck equipped with nine forks and is fed with pallet conveyor. Once a load is in position in front of the forks and the outbound trailer is in position adjacent to the load, the forks lift all eighteen pallets and deposit them on the back of the side-loading trailer. The loading process requires approximately one minute to complete.

The other material handling system to highlight at the Chiba brewery is a twin-shuttle AS/RS. The 11-aisle system can house 29,100 pallets in single-deep storage. Each 330-foot long, 100-foot tall aisle is equipped with two, twin-shuttle S/R machines. The system is equipped on each end with two levels of cart-on-track input/output conveyor. The system is capable of 1,210 pallet transactions per hour. Material is not allowed to sit in storage for more than six days.

Toyota Corporation's Kamigo Vanning Center

Toyota's 1989 performance was highlighted by sales in excess of $52 billion, a 31.8 percent domestic market share in Japan, and a 28.4 percent share of the Japanese automobile export market. The corporation employs nearly 70,000 people, and in addition to automobiles produces and sells industrial vehicles, modular homes and automated looms.

In July 1982 Toyota created the Toyota Logistics System (TLS) to ensure that the manufacturing concepts defining the world renowned Toyota Production System (TPS) would be executed throughout the logistics network. As a part of the process one of the managers responsible for the implementation of the TPS throughout many of Toyota's production plants was assigned to manage the TLS. As a result the JIT concept, *kanbans*, production smoothing, mixed models, no loss of resources, variability and problem visibility, visual control methods, worker involvement, zero defects, and so forth, are becoming commonplace in logistics operations at Toyota.

The Kamigo Vanning Center (KVC), managed under the Toyota Logistics System, is a 430,000 square foot kitting operation for Japan-source parts used in assembly operations at New United Motor Manufacturing, Inc. (NUMMI) in Fremont, CA and at Toyota Motor Manufacturing Canada (TMMC). The facility stocks and ships engine, transaxle, transmission, press, and assembly parts.

The operations at the KVC center around 12 kitting lines. Lines are supplied from a reserve storage area (one-half day's stock on hand) and are stocked from the back with counterbalance lift trucks. A single operator is assigned to each side of a kitting line. A kitting line operates very much like an auto assembly line. An AGV travels through the line with a modular container on board. As the AGV moves down the line, operators retrieve parts located along the line and place them in the modular containers. At the end of the line the container is complete and is transported on the AGV to the trailer loading operation.

The trailer loading operation is also automated. Loads are automatically moved into trailers with a conventional counterbalance lift truck that has been converted into an automated guided vehicle. Guide rails have been erected on the dock to steer the truck into the back of the trailer. Upon entering the trailer the lift truck uses the side walls for guidance further into the trailer.

One of the other impressive aspects of the operation is the extensive use of *kanbans*, loudspeakers, boards, lights, buzzers, and in some cases music to signal changing demand patterns, the introduction of a new product line, a line changeover, or a maintenance problem. Another unusual aspect was the conversion of conventional lift trucks and conventional pallet trucks into an inexpensive, 23-vehicle automated guided vehicle fleet.

Shiseido Cosmetics

Shiseido is one of Japan's largest distributors of cosmetic products. With 25,000 stores and five major distribution centers in operation, 1988 sales exceeded ¥340 billion.

Shiseido's 110,000 square foot Nagoya distribution facility is Shiseido's newest. The single-story facility services 5,500 Shiseido outlets and was completed in November 1989 at a total investment of ¥2.9 billion ($24 million). The investment in storage and handling equipment was approximately ¥700 million ($5.5 million) and includes 45 intelligent-picking vehicles ($25,000 each), a robotic depalletizer, a twin-shuttle micro-load AS/RS, and an extensive network of roller conveyor for tote handling. Four material handlers, 9 lift truck operators, 100 part-time (5.5 hrs/day, all female) order pickers, 3 managers, and 4 contract computer operators are employed at the facility. The work force works 6 days a week to ship an average of 240,000 cases.

Receipts are inducted into collapsible totes for storage in a twin-shuttle micro-load AS/RS. Replenishment requests from the AS/RS to a forward picking area are generated automatically, and are based on a minimum 2.5 day-time supply for all items in the forward area.

Order picking in the forward area (bin shelving and flow rack) is centered around an intelligent picking cart and a light-aided picking system. Computer generated order picking tours are created overnight and stored on smart cards. The cards are read by microprocessors on each picking cart. The microprocessor works in conjunction with a radio frequency communications system to (1) illuminate a map of the minimum distance picking tour on the front of the cart, (2) illuminate LEDs on the warehouse locations that must be visited, and (3) illuminate an LED on the cart that designates the container the item should be placed in. Other than the on-board microprocessor, the carts are simple, light, manual push carts equipped with tote pans for order sortation.

The motto for justifying the system was "Don't seek, don't think," a reference to the simplicity of the operation. The simplicity permits a picking rate of between 120 and 140 lines per hour, an accuracy rate of 99.998 percent, and training periods of less than three days. The system was also justified on a 20 percent total cost reduction and a 30 percent reduction in inventory. All warehouse operations are controlled with an IBM AS400.

APPENDIX F. GLOSSARY

ARC	AS/RS Real-Time Controller
AEM	Automated Electrified Monorail
AGV(S)	Automatic Guided Vehicle (Systems)
AS/RS	Automated Storage/Retrieval System
CCD	Charge Coupled Device
DC	Distribution Center
FA	Factory Automation
IPV	Intelligent Picking Vehicle
IR	Infrared
JIT	Just-in-Time
LIM	Linear Induction Motor
MB	Megabyte
OCR	Optical Character Reader
P&D (P/D)	Pick Up and Deposit
RF	Radio Frequency
ROU	Read-Out Units
RTS	Real-Time System
SKU	Stock Keeping Unit
STV	Sorting Transfer Vehicle

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